2) Construction Cost of Sanitary Latrine

The cost of a surface latrine, a pit latrine and a septic tank on average for installation and construction as reported by the above 18 Town Water Supply and Sanitation Project is given below:

Surface water latrine	-	Tk. 112
Pit latrine	-	Tk. 2,301
Septic tank	-	Tk. 9,600

Users satisfaction of the three majors sanitation facilities is determined to be as follows:

Surface water latrine	-	15%
Pit latrine	-	70%
Septic tank	-	100%

3.2.4 Operation and Maintenance

DWASA is responsible only for operation and maintenance of sewerage while DCC is responsible for all other sanitary facilities in Dhaka. In Narayanganj as there is no sewerage, municipality is the sole responsible organ for operation and maintenance of sanitary facilities. Due to improper operation and maintenance sewer line is blocked and broken in various places. There are even sewage disposal points towards low lands other than the designated Pagla Treatment Plant and are not at all maintained. Most of the septic tanks are broken and full of sludge and also many street manholes are blocked and without lid. Some even abandoned. Cleaning is mostly done by hired sweepers. The frequency of cleaning is very irregular hence it is difficult to relate it to the sanitation facility.

It is understood that atleast 50% of the septic tanks and pit latrine are never desludged. Mostly hired cleaners do the desludging job. The average amount people pay to get their latrine or septic tank desludged/emptied is in the range of Tk. 300/ = and Tk. 400/=.

3.2.5 On-going Sanitation Improvement Projects

The feasibility study was undertaken by ADB / UNDP under a sub-contract to the Housing Development Project (HDP) in 1985. The HDP is within the Urban Development Directorate of the Ministry of Works. The study comprised two study components namely Subcontract A and Subcontract B. Location of these study areas are as follows:

- Subcontract A, the old Dhaka project, involves the upgrading and development of sections of the oldest part of of the city.

- Subcontract B, the Mirpur project, concentrates on the development/improvement of new urban areas in Mirpur, a relatively modern part of the city .

1) Sub-contract 'A' (Housing Development Project, Old Dhaka)

Project area covers Shaheednagar, Islambag and Rasulpur in Old Dhaka. One of the most obvious problems within the project area is the poor sanitary facilities. The situation is aggravated by the absence of sufficient drainage facilities for stormwater and sullage water from the house holds. Though DWASA sewer encompasses the whole project area, the sewerage coverage is not very significant. In general, a very small part of the population has proper sanitary facilities such as sewerage, septic tanks, pit latrines. Due to very poor maintenance (desludging) even these facilities do not function satisfactorily. Appropriate water seal latrines are few in number and are mainly located in pucca houses along the main paved access roads. Some times the septic tank are shared with other households.

The majority of the population who are slum dwellers rely on katcha latrines or hang latrines (make-shift latrine) without water seal and mostly built above ponds, ditches or the river. This project is aimed at improving this deteriorated living conditions among low income communities in Islambag, Shaheednagar and Rasulpur. The project is targeted for completion by 1996 to 1997 in the name of "Environmental Improvement Project" sponsored by LGRD and Co-operative local government division, with the technical assistance of UNDP. The executing and operational agency is DCC. The project has several components namely sanitation, community development, water supply, roads and footpaths, local drain improvement and khal rehabilitation.

Under the sanitation component 3,690 twin pit pour-flush latrines, 980 single pit latrines and 826 communal latrines to be constructed in the project area. According to DCC, the implementation phase will commence in 1992.

The mechanism of cost recovery envisaged for the sanitary facilities to be provided is given below.

Single Pit Latrine

Total cost per unit (excluding superstructure) is Tk. 3,500.00. This will be recovered by installment payment of Tk. 105.00 per month in 3 years

Twin Pit Latrine

Total cost per unit (excluding superstructure) - Tk. 5,000.00. Recovery by installment payment - Tk. 150.00 each month in 3 years

2) Subcontract 'B' (Housing Development Project, Mirpur).

An extensive septic tank waste disposal system exists in the project area of Mirpur as reported by the Housing and Settlement Directorate. The effluent from these septic tanks is discharged to lowland open areas through a piped sewer system with several outlets.

Low income groups mainly use insanitary facilities, though some use pit latrines. Approximately 25% of these people use open areas for human waste disposal and remaining 75% use some form of facility which is mainly open pits, including some shared arrangement.

According to Appraisal Report by ADB in 1988, the existing sewered area at Mirpur discharges its wastewater through 9 disposal points towards low-lying areas.

In order to improve the living condition of Mirpur, this Subcontract 'B' proposes, small bore sewer, infill development (land reclamation for new housing), basic infrastructure improvement like water supply, sanitation, gas, electric supply and solid waste disposal etc. The project will be implemented until 1994 under the name of Dhaka Urban Infrastructure Development Project with ADB finance.

There are three major components namely small bore sewer, infill development, roads and footpaths improvement to be executed by WASA, HSD and DCC respectively. Small bore sewer component,which includes construction of 123 km of new sewer lines with 5 pump stations, is aimed at both the rehabilitation and expansion of the existing sewered area. Even after the project implementation wastewater will be discharged untreated towards low-lying areas, which is not appropriate on a long term basis.

3.2.6 Sanitation Improvements Measures

The existing sanitary conditions and the available facilities and their operation and maintenance are very unsatisfactory in Dhaka. This is particularly so with the low income population living in makeshift (Katcha) housings as emphasized in the foregone sections.

The priority actions necessary for the improvement of sanitation are itemized below. They are elaborated in details under the FAP-8B comprehensive environmental management plan.

1. Organizing a public sector based scheme by the local authority like DCC/DWASA, Municipality for desludging, transport and sanitary disposal of septic tank sludge.

2. Provision of twin leaching pit toilets, if necessary at a subsidized rate atleast on a communal basis as public toilets, for low income population with markeshift or no toilet facilities.

3. Conversion of bucket latrines that remain into twin leaching pit type toilets and prohibition of construction of bucket latrines for new housings by the local authority concerned.

4. Education and campaign to increase the awareness of general populance on the importance, means, and benefit of mitigating fecal-oral transmission of disease by adopting sanitary practices and customs.

3.3 Impact on Living Environment

The project in itself has only beneficial effects on living environment as flood mitigation and drainage measures contribute to public health improvements.

However, as the project is aimed at future urban development as its prime objective, the prime effects/demands that would be generated by future population increase in the priority area is determined as done in the case of Master Plan study (ref. Table F. 13 of Supporting Report F, Master Plan).

The basic living environmental demand parameters considered are potable water requirement, pollution load generation and solid waste generation by the inhabitants.

Employing the same criteria as used in the Master Plan study of Supporting Report F, the potable water demand in the priority area in 2010 is determined to be 1300 MLD, an average annual increase of 14.8% from the existing demand of 438 MLD in 1990.

The pollution load generation is estimated to increase to 260 ton BOD_5/day from the existing one of 110 ton BOD_5/day, with an average annual increase of 12.3% while, the solid waste generation in 2010 is estimated at 5075 ton/day against the existing one of 1880 ton/day in 1990, with an average annual increase of 13.5%.

The necessary means to meet these demands shall be taken up with progressing urbanization in the form of future water supply, sewerage and sanitation and solid waste management development programs.

4. Environmental Monitoring

4.1 Significance of Retarding Area

In the feasibility study, the priority monitoring requirement that would be generated by the implementation of the project in the whole priority area of 340 sq.km is identified.

The proposed retarding areas of internal drainage and subsequent pumping are identified to be the most comprehensive future environmental monitoring stations of water quality, though they alone may not be sufficient. This is due to the fact that a retarding area would be temporary storage location of the whole surface run-off from the drainage basin concerned. Such surface run-off include the pollution load run-off due to all human and other related concerns such as domestic, institutional, industrial, agricultural and other activities.

Accordingly, the base line water quality under the existing conditions in the proposed retarding areas were monitored both during flood season (October 1991) and dry season (February 1992) at fifteen (15) locations. The sampling locations are shown in Fig. C. 1. The water quality parameters measured respectively in field and in laboratory are the same as those of master plan study and itemized below.

(1) Field measurement : Temperature, Colour, Odour, Turbidity, PH, Electric Conductivity (EC) and Total Dissolved Solids (TDS).

(2) Laboratory measurement : Suspended Solids (SS), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Organic Nitrogen (Org-N), Ammonia Nitrogen (NH_4N), and Fecal Coliform Density (FC).

The results of water quality analysis both during flood season and dry season is summarized respectively in Table C.4 and Table C.5.

4.2 Water Quality Evaluation

4.2.1 Basic Consideration

The baseline water quality conditions as measured both during flood and dry seasons in the proposed retarding areas were evaluated based on the important beneficial uses of aquaculture (fishery), irrigation and other water contact activities.

The criteria of evaluation is described in Supporting Report F, Master Plan (ref. Chapter 6).

It is to be noted that though most proposed retarding areas are just low lands and yet to serve their purpose, still three (3) sampling locations in Dhaka West of FAP-8B project area, namely, location No. 12, 13, 14 of Fig. C.1, already function as defacto retardings areas to some extent due to the existence of the DFPP embankment constructed by GOB after the 1988 floods. However, the drainage pump facilities are yet to operational. Hence the present condition, also the condition during the time of both sampling, reflects neither without nor with project state.

This precarious situation and its environmental implication is documented in previous reports, notably, the Progress EIA Report by DOE in 1990 and the FAP-8B Feasibility Report of 1991, and is not reproduced here. However the situation will be rectified with the implementation of FAP-8B project.

Moreover, all the six (6) number proposed retarding areas in DND, as the whole area is enclosed by polder under existing condition, already serve their purpose unintentionally to some extent. They are drained by the single irrigation cum drainage pump facility of the DND project in Demra.

Nevertheless, as long as the land use of this DND area remain predominantly agricultural without much urban and industrial use, the water quality aspect need not require much consideration unlike Dhaka West and the southern portion of Dhaka East at north of DND area. Still there are jute milling industry predominantly in Narayanganj, and also in DND area, the major source of pollution generation in these areas.

The southern portion of Dhaka East area, which is proposed to be enclosed with compartments DC-4 and DC-3 as per the flood mitigation plan (ref. Fig. B.12 of Supporting Report B), drains also the drainage related area of Dhaka West via Segunbagicha and Begunbari Khals.

This drainage related area of Dhaka West includes both highly urbanized and industrialized areas of Motigheel and Tejgaon and the high-class residential areas of Dhanmondi, and Banani-Gulshan.

Hence the major contributor of pollution load discharge into the southern portion of Dhaka East, under the existing condition, is the above drainage related area of Dhaka West. While the pollution load generated within this Dhaka East area is yet to be significant.

Detailed information on the drainage aspects of Dhaka East and DND could be referred to respectively in Chapter 3 and Chapter 4 of Supporting Report E.

4.2.2 Evaluation

This 15 sampled locations (ref. Fig. C.1) covered a portion of the retarding area of the proposed project, two (2) locations in Narayanganj West (No. 1 and No.4) four (4) locations in DND area (No. 2~3, No. 5~6), five (5) locations in Dhaka East (No. 7~11), all in Balu River flood plain, and four (4) locations in Dhaka West (No. 12~15).

As expected, in an overall sense critical condition in water quality occurred under dry weather flow conditions, in dry season, during which the major composition of run-off is wastewater discharge.

However, in some specific instances rainy season water quality may be deteriorated than that of dry season, in low lying areas. This is because pollutants, that would otherwise be retained in or near the point of their generating source during dry season, are get washed off due to the availability of large quantity of rain-fall run-off as their carrying agent.

Water quality wise, if not quantity wise, all the sampled water bodies in rainy/flood season, except that of Shasongaon pond of Kashipur belonging to Narayanganj West region of the project (location No. 1 in Fig. C.1), are found to be suitable for all beneficial use including as a source of potential water supply with treatment.
Leachete run-off from nearby solid waste dump site of Shasongaon pond, which the pond water body itself encompassed in rainy season but not in dry season, was suspected to be the possible cause of the much deteriorated rainy /flood season water quality in comparison to that of dry season (ref. Table C.4 and Table C.5). The flood season sampling results indicate a virtual anaerobic condition, while that of dry season a normal unpolluted water body.

Moreover, a complaint of industrial pollutant run-off during rainy season from milling industries, affecting the water quality of Nayamati bil in DND area (location No.2), was made by local residents. It was reported that both the water and the captured fish in this bil taste bitter in rainy season, but not so in dry season.

It should be emphasized that all proposed retarding areas of Dhaka East (sampling location No. 7~11) are a large sheet of navigable water body, virtually a portion of Balu River, during rainy/flood season. This vast dilution and pollution wash-off effect of the river is responsible for the excellent flood season water quality of these locations in comparison to that of dry season. Also this "benefit" of annual flushing of pollution by the river will disappear with the construction of embankments, which would be further exacerbated by subsequent urban and other developments, unless the necessary pollution control measures targeting the sources of pollution load generation are undertaken. However, the drainage pumping facility will beneficially contribute by reducing the retention of polluted water in the retarding area, to some extent.

Such pollution control measures to tackle the already existing urban and industrial area in Dhaka West, even with the existence of sewerage system, is far from adequate. This is amply demonstrated by the extremely poor dry season water quality, exhibiting anaerobic condition, in all major khals carrying the city run-off, rendering them unsuitable for any beneficial use.

The dry season sampling results of Keodanga bil and Trimohani khal (location No. 7 and 8 of Fig. C.1 and Table C.5), which receive their run-off respectively via Segunbagicha cum Gerani khal from Motigheel commercial area, and Begunbari cum Gerani khal from almost the whole commercial and industrial area (Tejgaon), both of Dhaka West, is sufficient to justify the above point. Similar condition were also noted during water quality sampling for Master Plan (ref. the dry season sampling results for location No. 15, 16 and 21 of Table F.10, Supporting Report F of Master Plan).

Finally, the baseline water quality of the following eight (8) sampling locations are assessed to be suited for all major beneficial use, including aquaculture/fishery, on a year round basis, based on both the analysis results of rainy/flood and dry seasons.

Location No. 2 - Nayamati bil in DND area
Location No. 3 - Kadamtoli pond in DND area
Location No. 4 - Shimrail pond in Narayanganj West area
Location No. 5 - Matuail khal in DND area
Location No. 6 - Pagla pond in DND area
Location No. 9 - Gazaria bil in Dhaka East area
Location No. 10 - Baraid Bazar pond in Dhaka East area
Location No. 11 - Dhamaahl bil in Dhaka East area

The water bodies of best water quality are identified to be location No. 9 and No. 11, both of which are rural remote locations of Dhaka East.

4.3 Recommendation on Monitoring

Institution of stream water quality monitoring station in the retarding areas, in the internal drainage channels (Khals) leading to those retarding areas and in the Balu-Lakya River, as required, would become necessary with the implementation of this

FAP-8A F/S project in Dhaka East, DND and Narayanganj West and the progressing urban, industrial and other developments. This will assist in formulating and implementing the necessary pollution control measures abreast the change in land use.

The parameters of monitoring shall be decided based on the inventory data of the existing sources of pollution load generation due to human living environment, industry and agriculture. However, it is strongly recommended to monitor atleast all those living environment related water quality parameters, as measured by the Study Team, listed in Section 4.1. Additional parameters may be decided depending on the type of other industrial and agricultural activities in the drainage basin concerned.

The frequency of monitoring will depend on the degree of time series variation in water quality, but a minimum frequency of two (2) times a year, once each during dry season (December ~ February) and rainy season (July ~ September) is recommended in order to account for the maximum annual deviation in water quality.

Priority monitoring locations are the two (2) retarding areas of FAP-8B project (location No. 13 and 14 in Fig C.1) and the related khals, namely, Ibrahimpur Khal and Kalyanpur Khal of Dhaka West, Begunbari Khal in Dhaka East at down stream of Rampura, and river water quality in Balu River, preferably upstream of Balu ~ Lakya confluence in Demra. These are the most urbanized and fast urbanizing reaches of Dhaka city, at present.

It is also recommended to monitor for industrial pollutants, in Begunbari khal at Rampura, as it carries run-off from Tejgaon industrial area as well.The parameters shall be decided based on the inventory of industrial activity in this area.

It is worth to mention that for a small and confined basin like DND and Narayanganj West, monitoring the water quality in some selected retarding areas only would suffice for an overall assessment of both the pollution load discharge as well its run-off. However, for large basins like those of Dhaka West and East, monitoring of water quality in some related internal drains (khals) in addition to those retarding areas would be required due to the potential deviation between pollution load discharge at urbanized/industrialized upstream reaches and its run-off to retarding areas at downstream.

Finally, it is to be emphasized that monitoring in itself is just a data collection process. Unless the derived data are translated into action programmes by the agency concerned, DOE, to identify and regulate the polluters, it has the danger of manifesting as a worthless effort of resource wastage. Moreover environmental improvement measures do not always require monitoring results to justify the required action, as already pointed out in Section 9.2 of Supporting Report F, Master Plan.

Urban and industrial pollution control measures are the only means to render the internal drainage channels (khals) and retarding areas to be suited to a varriety of beneficial use. Otherwise, they would simply serve as pollution transport, storage and discharge locations.

5. Environmental Effects

Environmental effects by the project will be predominantly beneficial though adverse to some extent. Specifically adverse effects would be social in nature that is felt by the immediate concerns in the vicinity of project implementation, such as those population displaced in making way for the project facilities and others.
These effects would be both of short term and long term and caused directly and indirectly by the project. Such effects are delineated below.

However, it is emphasized that the benefits expected by the project implementation is overwhelming, for both the existing and future urban area of Dhaka, and the anticipated adverse effects in no way could justify the vice-versa. A comprehensive evaluation of the project is shown in Table I.11 of Supporting Report I.

5.1 Beneficial Effects

Major beneficial effects of short and long term realized by the project are summarized below.

5.1.1 Short Term

1) Employment opportunity

Employment opportunities will be generated for construction works. This is considered a short term benefit as it would disappear with the completion of construction activities. In order to maximize such employment opportunities labour intensive methods are adopted as far as possible. Also technical training opportunities on design and construction technology are availed of for engineers

/ technocrats. The total man-year of construction activity, covering Dhaka East, DND and Narayanganj West project components of this feasibility study, is estimated at 66,513.

5.1.2 Long Term

1) Flood damage mitigation

Mitigation of flood damage to properties, facilities and other economic activities will be realized, the basic reason for this project formulation. Also psychological stress and flood induced displacement of people will be eliminated. The population saved from inundation in the year 2010 from a 1988 year scale floods in the F/S area is estimated to be about 5.3 million. This is almost the existing (1990) population in the whole priority area of Greater Dhaka and Narayanganj (ref. Table C.1).

2) Enhanced land use potential

Enhanced land use potential of flood free lands for urban, institutional, industrial and agricultural uses would be realized. This will be reflected by increased land value. The land availability for multipurpose use, excluding those of water bodies and retarding areas, would increase to about 26,000 ha in 2010 from the existing area of about 18,300 ha.

3) Public health improvement

Public health improvement by mitigation of cross contamination of water resources inherent to flooding, and the resultant waterborne epidemics is very significant. Flood mitigation would also facilitate the applicability of on-site sanitation/human waste disposal means such as pit latrine/leaching pit.

The additional economic loss due to waterborne disease caused by 1988 floods is estimated to be Tk. 75.7 million. Both this loss and hence the benefit of its mitigation by the project will increase with increasing population.

4) Generation of employment

Permanent employment along with technical training opportunities for operation and maintenance of the flood control and drainage facilities will be generated. In consideration to the long term nature of operation and maintenance requirements of the projects facilities constructed, the O/M related employment is assessed to be a long term benefit.

5.2 Adverse Effects

Significant adverse effects of short and long term are given below.

5.2.1 Short term

1) Severance

Severance in general implies inconvenience or difficulties which may be physical or psychological in nature experienced by those who are well adapted to the way of living under the conditions without project and are forced to re-adapt to the change in way of living imposed by the project.

Such severance effects by the construction of embankment flood/wall are as follows:

Interference to accessibility due to embankment / flood wall between the protected and unprotected area. This in effect means separation of communities. However, in case the embankment is along riverine area this effect is lessened as river itself separates the community. Interference to accessibility to ones property due to flood walls is also a severance effect.

It is to be noted that a future effective transport network system utilizing the embankments as roads would contribute to the enhancement of accessibility, far out weighing the short term severances.

2) Navigation

Passenger and material transportation by boats is widely prevalent in East Dhaka Balu River flood plains, particularly, during flood season.

In the absence of any all weather land based road link between Balu River and Rampura-Biswa Road such a water based transportation is more a necessity than an option.

With the implementation of Balu River flood mitigation embankments and the subsequent urbanization a more efficient road based transport network would be developed as the alternative link. The sub-embankments of compartmentalization are major potential future link roads. This change over to road transportation will be beneficial to the national economy.

However, this change over from water based to road based transportation may be detrimental to the livelihood of the boatmen engaged in this trade under the existing conditions. In order to assess the significance of this social impact on boatmen, the study team conducted an interview survey with toll collectors at eleven (11) major boating terminals of Dhaka East in November, 1991. The results revealed that 2625 person are employed by this boating business in East Dhaka. The survey is dealt with in details under social impacts in Supporting Report I.

Though this social impact may be significant as far as these boatmen are concerned, still the alternative road transportation development would open a more lucrative multiple employment opportunities than boating. Some of these people may be forced to this boating business, under the existing flooding conditions, in the absence of a suitable alternative employment opportunity.

Moreover, a compartmentalized development of flood protection embankments in stages, as proposed for East Dhaka having four (4) cells, would facilitate a gradual change over from water based to land based transportation with both functioning concurrently during the initial development stages. This would help in moderating the social impacts on those boating employed persons by providing a time frame to switch over to alternative employment, and hence an orderly adaptation to the environmental change.

3) Construction effects

The major construction activities involves earthen embankment by filling and compaction, khal improvements such as excavation and widening and pump stations.

The significant effect will be vibration and noise pollution and to some extent air pollution due to dust by the construction activities. However, embankment construction is widely practised in Bangladesh, and the major embankment sites along Balu river and the retarding areas of pump stations are rural areas which means these effects will not be very significant.

However some khal reaches of improvement are in urban areas, where such works would interfere with human actives. Furthermore, excavation and other earth works would temporarily raise the turbidity of khal water, affecting the water quality. Nevertheless, as most khals are polluted as per their base line conditions, these added short term effects may not be significant. In order to minimize interference with human activities night time work schedule may be adopted, if necessary.

5.2.2 Long Term

1) Resettlement

Resettlement of population and other facilities like factories displaced by land acquisition and the subsequent demolition of houses and other buildings for the project facilities like embankments and khal improvements is an important negative social impact of the project. This is considered to be relatively long term in consideration to the movement and the subsequent adaptation involved by those moved.

Duly recognizing the social significance of this involuntary displacement of those people whose houses would be demolished to make way for the construction/ improvement of embankment/khals, a sampling questionnaire survey was conducted by the study team in December 1991 targeting the would be displaced residents, in order to get to know their psychological/mental perception regarding displacement. The survey covered residents of 61 would be acquired houses located en route to the proposed embankment along Balu River in Dhaka East.

The analysis results of the sampling survey is elaborated in details under social impacts in Supporting Report I.

A majority of the residents surveyed, about 70%, had no objection to displacements provided they received adequate compensation to venture into a "new life". It also became clear that most residents expect house compensation be higher than current selling value of house, reflecting their anxiety of being forced to build a new house costing more than the current value of house. Such a higher expectation of compensation for building a new house is reasonable from a sociological view point so that those displaced would not end up as slum dewellers as happened in the past with most resettlers in many developing countries.

Accordingly, a per building compensation costs of Tk. 40,000 is assumed against the estimated current value of Tk. 30,000 by by the Study Team, based on this interview survey results.

The total population to be resettled due to the implementation of this FAP-8A feasibility study in Dhaka East, DND and Narayanganj West is estimated at 7000. The total amount of compensation of house and other buildings becomes Tk. 328 million. This cost is incorporated as a negative benefit by the project in the cost-benefit analysis (ref. Supporting Report I).

2) Living environment

This is a major indirect consequence by the project, due to subsequent urbanization and the resultant potable water demand, pollution load and solid waste generation by the increased population. The mitigatory measures are the provision of such basic public health amenities in future. In this regard, the water quality monitoring of retarding areas would also help in assessing the change in condition with respect to pollution load generation and the required action with progressing urbanization.

These living environmental demands are quantified in Section 3.3.

3) Change in land use on ecology

The existing agricultural and open water capture fishery lands, other than those retarding areas, would be changed to urban use in principle, another indirect consequence. Nevertheless, agricultural productivity and culture fishery will be enhanced in the flood protected lands, provided land is reserved for such uses. The retarding areas are suited for such uses atleast during dry season.

As evident from Table C-1, the agricultural land use in the priority area will decrease from 43.5% in 1990 to just 7% in 2010, resulting in a loss of 12,366 ha of agricultural land to urban use, an inevitable indirect consequence of this project. This loss in financial terms, as total net value added loss of agricultural production, is estimated at 309 million Tk. (ref. Section 2.2.1).

Moreover terrestrial homestead floral species and terrestrial domestic faunal species will become predominant with progressing residential development at the expense of both the aquatic floral and faunal species, and terrestrial faunal species of wild origin.

However, in consideration to the availability of vast flood plains around the priority area and their high cropping intensity in comparison to the priority area that includes the flood plain management area of Master Plan, effects of change in land use to urban in the priority area is assessed to be not very significant, not only with respect to both the agriculture and open water capture fishery of productive ecological elements but also the general elements of flora and fauna.

Table C.1 Existing and Future Condition in Priority Area

Existing Condition in 1990

Item	Land Area (ha)	Builtup Area (ha)	Agriculture Area (ha)	Water Body (ha)	Annual Flood Area (ha) *		Population in 1990
					External	Internal	
Dhaka West	14,445	9,601	2,367	2,477	3,959	597	3,804,494
Dhaka East	11,862	2,313	8,814	735	7,850	417	637,500
DND	5,679	2,174	3,173	332	0	410	448,590
Narayanganj West	1,863	1,312	464	87	111	87	470,449
Total	33,849 (100%)	15,400 (45%)	14,818 (44%)	3,631 (11%)	11,914 (35%)	1,511 (4.4%)	5,361,033

Future Condition in 2010

Item	Land Area (ha)	Builtup Area (ha)	Agriculture Area (ha)	Potential Water Body (ha)	Retarding Area (ha)	Population in 2010
Dhaka West	14,445	12,496	602	1,347	980	6,385,301
Dhaka East	11,862	8,550	1,310	2,002	1,675	2,201,935
DND	5,679	4,270	532	877	682	1,313,749
Narayanganj West	1,863	1,720	8	135	128	926,820
Total	33,849 (100%)	27,036 (80%)	2,452 (7%)	4,361 (13%)	3,465 (10%)	10,827,805

* All flood condition refer to that of before 1988 floods - prior to DFPP embankments.
Internal flood area represents area flooded in built-up area.

Table C. 2 Existing Crop Production in Priority Area (1991)

Crop	Cropped Area (Ha)	Yield (Ton/Ha)	Total Production (Ton)	Production Cost			Market Price		
				Cost/Ha (Tk.)	Cost/Ton (Tk.)	Total Cost (1000 Tk.)	Price/Ha (Tk.)	Price/Ton (Tk.)	Total Price (1000 Tk.)
1a Boro (L)	983	1.90	1868.0	6,200	3,263	6094.6	12,827	6,750	12609.0
1b Boro (HYV)	10,545	3.50	36908.0	10,700	3,057	112831.5	23,170	6,620	244331.0
1c Boro (Imp.)	2,040	2.70	5508.0	7,300	2,704	14892.0	18,225	6,750	37179.0
1d T. Aus (HYV)	340	2.90	986.0	8,800	3,035	2992.0	21,141	7,290	7187.9
1e T. Aman (HYV)	4,605	3.30	15197.0	8,300	2,515	38221.5	24,058	7,290	110786.1
1f T. Aman (Imp.)	1,350	2.87	3875.0	6,100	2,125	8235.0	21,313	7,425	28771.9
1. RICE	19,863	3.24	64342.0	9,227	2,848	183266.6	22,195	6852	440864.9
2. WHEAT	130	0.80	104.0	5,600	7,000	728.0	8,320	10,400	1081.6
3. POTATO	185	12.40	2294.0	12,800	1,032	2368.0	66,960	5,400	12387.6
4. OIL SEEDS	850	0.50	425.0	3,300	6,600	2805.0	5,400	10,800	4590.0
5. PULSES	290	0.69	200.0	3,200	4,640	928.0	21,035	30,500	6100.0
6. VEGETABLES	1,085	19.20	20832.0	8,500	443	9222.5	96,000	5,000	104160.0
7. FRUITS	60	27.00	1620.0	-	-	-	324,000	12,000	19440.0
TOTAL	22,463	4.00	89817.0	8,873	2,219	199318.1	26,204	6,554	588624.1

Note : HYV - High yielding variety, L - Local variety, Imp. - Improved variety
Source: JICA, DND Project, BARC

Table C. 3 Future Hypothetical Crop Production in Priority Area

Crop	Cropped Area (Ha)	Yield (Ton/Ha)	Total Production (Ton)	Production Cost			Market Price		
				Cost/Ha (Tk.)	Cost/Ton (Tk.)	Total Cost (1000 Tk.)	Price/Ha (Tk.)	Price/Ton (Tk.)	Total Price (1000 Tk.)
1a Boro (L)	450	1.90	855.0	6,200	3,263	2789.9	12,825	6,750	5771.3
1b Boro (HYV)	10,698	4.10	43862.0	12,534	3,057	134086.1	27,142	6,620	290366.4
1c Boro (Imp.)	1,740	2.80	4872.0	7,571	2,704	13173.9	18,900	6,750	32886.0
1d T. Aus (HYV)	520	3.00	1560.0	9,105	3,035	4734.6	21,870	7,290	11372.4
1e T. Aman (HYV)	5,655	3.80	21489.0	9,557	2,515	54044.8	27,702	7,290	156654.8
1f T. Aman (Imp.)	1,370	2.87	3932.0	6,099	2,125	8355.5	21,310	7,425	29195.1
1. RICE	20,433	3.75	76570.0	10,629	2,836	217184.8	25,755	6,873	526246.0
2. WHEAT	150	1.25	188.0	8,773	7,000	1316.0	13,035	10,400	1955.2
3. POTATO	205	13.25	2716.0	13,673	1,032	2802.9	71,543	5,400	14666.4
4. OIL SEEDS	1,010	0.85	859.0	5,613	6,600	5669.4	9,185	10,800	9277.2
5. PULSES	370	0.70	259.0	3,248	4,640	1201.8	21,350	30,500	7899.5
6. VEGETABLES	1,505	19.50	29348.0	8,639	443	13001.2	97,502	5,000	146740.0
7. FRUITS	60	27.00	1620.0	-	-	-	324,000	12,000	19440.0
TOTAL	23,733	4.70	111560.0	10,162	2,162	241176.1	30,600	6,510	726224.3

Table C. 4 Flood Season Water Quality Sampling Results in Retarding Area (Oct. 1991)

Location		PH	EC	TDS	SS	DO	BOD	COD	Org - N	NH_4-N	FC
No.	Description		(Umho/cm)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(No./100ml)
1	Shasongaon Kashipur	7.7	397	156	52	0.6	37	84	1.3	1.2	1.4×10^4
2	Nayamati Bil	7.0	260	134	34	4.9	0.8	16	0.7	1.0	7.1×10^3
3	Kadamtoli Pond	7.0	220	112	28	5.8	2.9	20	1.1	1.1	3.5×10^2
4	Shimrail Pond	7.2	190	97	26	2.9	4.0	8	1.4	1.3	1.0×10^4
5	Matuail Khal	7.0	120	64	32	3.1	5.7	12	0.7	1.4	9.0×10^4
6	Pagla Pond	7.0	380	193	42	2.3	8.5	20	1.1	1.1	1.3×10^3
7	Keodanga Bil Manda	7.0	167	84	26	7.4	4.2	24	1.8	0.2	9.0×10^3
8	Trimohani Khal	7.6	113	57	23	7.9	4.0	14	0.8	1.0	4.4×10^3
9	Gazaria Bil Mad	7.0	71	30	18	4.3	3.9	16	1.0	0.2	$<1.0 \times 10^2$
10	Baraid Bazar Pond	7.0	51	26	20	7.5	2.0	20	1.7	0.9	2.0×10^4
11	Dhamaahl Bil	7.3	49	25	15	7.1	2.0	12	1.2	0.1	8.0×10^3
12	Alakdi Khal Mirpur-12	7.1	166	83	32	5.1	0.7	16	1.6	0.5	2.5×10^3
13	Agunda Bil Mirpur-1	7.0	94	47	18	4.9	2.0	8	1.7	0.2	7.0×10^2
14	Gabtoli Bus Station Pond	6.9	218	109	32	5.8	4.0	12	2.0	1.5	5.7×10^3
15	Kamrangir Char	7.0	91	48	33	5.8	1.3	12	1.5	2.3	2.0×10^4

Table C. 5 Dry Season Water Quality Sampling Results in Retarding Area (Feb. 1992)

Location No.	Location Description	PH	EC (Umho/cm)	TDS (mg/l)	SS (mg/l)	DO (mg/l)	BOD (mg/l)	COD (mg/l)	Org - N (mg/l)	NH_4-N (mg/l)	FC (No./100ml)
1	Shasongaon Kashipur	7.0	406	203	42	4.4	1.0	12	1.1	0.4	2.2×10^2
2	Nayamati Bil	7.4	107	536	92	2.3	15	36	1.1	1.0	8.0×10^2
3	Kadamtoli Pond	7.3	480	239	52	6.0	2.9	12	1.1	1.5	7.0×10^4
4	Shimrail Pond	6.8	751	375	53	5.0	2.0	8	0.9	0.3	3.0×10^4
5	Matuail Khal	7.2	777	389	95	3.6	12	27	0.6	1.8	1.0×10^2
6	Pagla Pond	7.6	543	272	42	6.1	1.4	16	0.7	0.4	1.4×10^3
7	Keodanga Bil Manda	7.2	328	263	110	0	50	125	1.0	24.0	$1.8\ 10^6$
8	Trimohani Khal	7.6	261	230	105	0	55	175	1.9	18.5	2.7×10^6
9	Gazaria Bil Mad	7.0	394	197	88	4.6	2.4	12	0.5	0.2	8.0×10^2
10	Baraid Bazar Pond	7.0	382	191	45	6.1	0.7	8	0.6	1.5	1.2×10^3
11	Dhamaahl Bil	7.2	133	64	49	5.9	0.3	4	0.6	1.0	6.0×10^2
12	Alakdi Khal Mirpur-12	7.3	265	132	100	1.4	15	42	1.2	0.7	3.5×10^4
13	Agunda Bil Mirpur-1	6.9	785	392	24	7.1	1.6	8	0.4	4.3	1.4×10^3
14	Gabtoli Bus Station Pond	7.3	851	425	43	3.4	12	45	1.4	6.0	4.0×10^2
15	Kamrangir Char	7.4	558	279	22	2.7	7.7	10	0.4	15.5	3.0×10^4

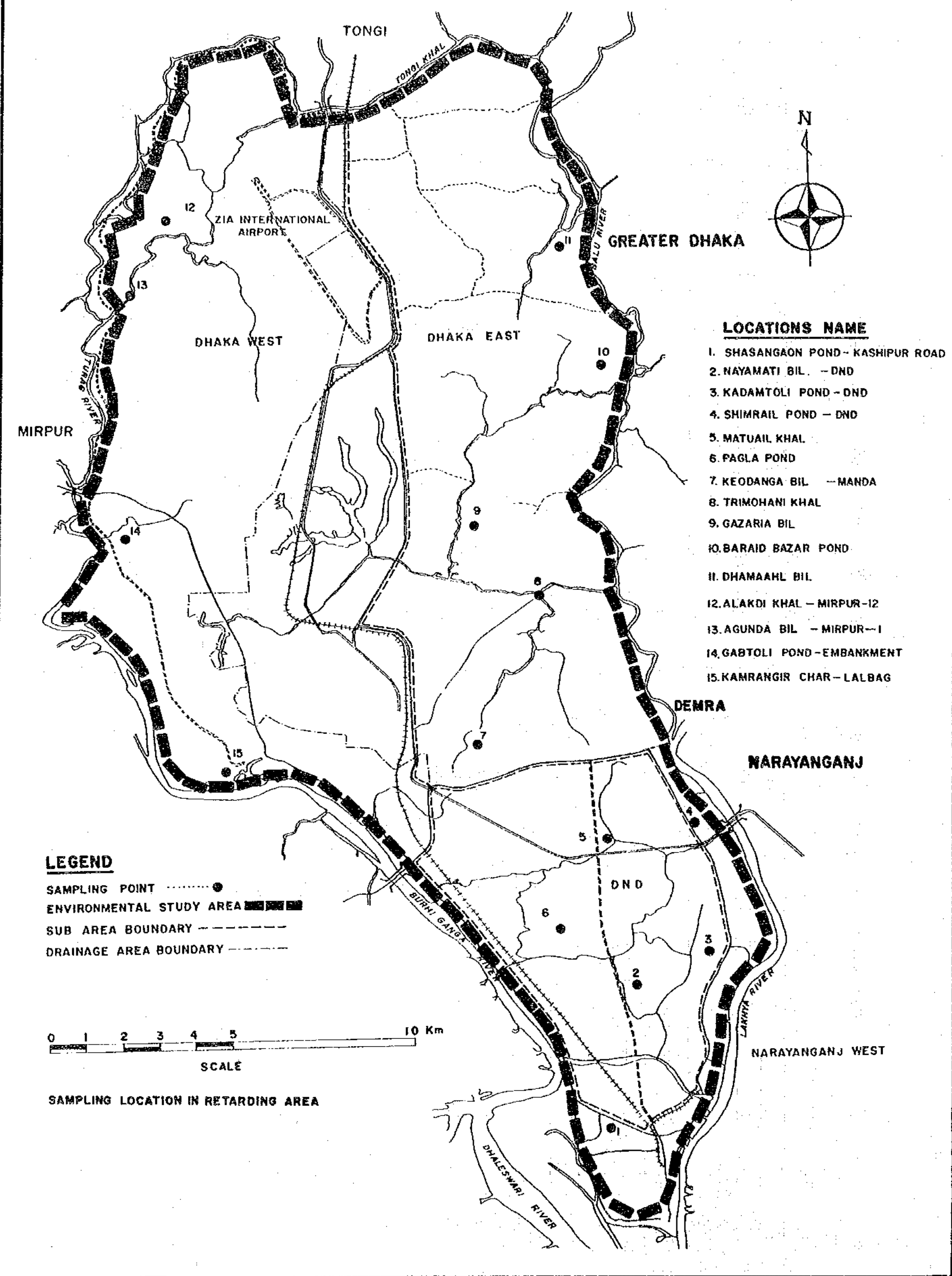

FIG. C. 1 WATER QUALITY SAMPLING LOCATION IN PRIORITY AREA

GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH

SUPPORTING REPORT D
METEOR-HYDROLOGY

SUPPORTING REPORT D : METEOR-HYDROLOGY

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SUPPORTING REPORT D : METEOR HYDROLOGY

1. General

As the feasibility area (the study area) is included in the master plan area, meteorological and hydrological descriptions in this report overlaps that of the Master Plan Report. Furthermore, supplemental water level data are collected and analysed and hydraulic simulations for drainage areas are conducted.

2. River and Khal System

2.1 River System

The study area as well as the master plan area is surrounded by tributaries and distributaries of three famous international rivers of the Ganges, the Brahmaputra and the Meghna Rivers.

The river system of the master plan area is shown in Fig. D.1 and listed below ;

(1)	Dhaleswari River	:	Distributary of the Jamuna River
(2)	Bansi River	:	- ditto -
(3)	Turag River	:	Distributary of the Old Brahmaputra River
(4)	Buriganga River	:	- ditto -
(5)	Balu River	:	Tributary of the Lakhya River
(6)	Lakhya River	:	Distributary of the Old Brahmaputra River
(7)	Karnatali River	:	Distributary of the Dhaleswari River and joining with the Turag River
(8)	Tongi Khal	:	Connecting the Turag River with Balu River

The study area is surrounded by the Tongi Khal in the north, the Balu River and the Lakhya River in the east, the Dhaleswari River in the south and the Buriganga River in the west. Above river system sometimes causes external floods by the big flood discharge through the Ganges and the Brahmaputra-Jamuna Rivers or the high backwater stage of the Meghna River.

Water levels of the above river system are the lowest in January-February and the highest in August-September as shown in Fig. D.8.

2.2 Khal System

Fig. D.2 shows the khal system of the study area. There are three big khal networks in the study area. They are the khal system of DND, the Begunbari Khal and the Jamair Khal in the Greater Dhaka East. The khal system of DND is composed of like braided network. But the khal systems of the Begunbari Khal and the Jamair Khal are composed of simple network.

3. Meteor-hydrology

The climate of the study area is classified as tropical monsoon type, characterized by three seasons of monsoon, post-monsoon and pre-monsoon. The monsoon is the rainy season normally from May to October during which 90% of annual rainfall occurs. Post-monsoon is the dry season from November to December. Pre-monsoon is the transition season between the rainy season and the dry season during which some rainfall occurs. Annual average rainfall in Dhaka is about 2000 mm.

In the beginning of the monsoon and the post-monsoon , cyclones with destructive winds hit Bangladesh. But, Dhaka area is almost always outside the affected area.

Average temperature varies from about 20^0C in December and January to about 30^0C in April to September. Maximum temperature sometimes exceeds 40^0C in March and April. Monthly average evaporation varies from 80 to 130 mm. It is the lowest in November and the highest in August.

Table D.1 shows the climatic conditions in the Study Area.

4. Features of Storm Rainfall and Flood Water Level

Storm rainfall and flood water level are the main factors of causing internal floods and external floods to the study area respectively. In this chapter, features of the storm rainfall and flood water level are described by using the results of the Master Plan Study.

4.1 Hydrological Observation Networks and Available Data

Hydrological observation networks in and around the study area as well as the master plan area is shown in Fig. D.1. There are ten (10) active and two (2) closed rainfall gauging stations and thirteen (13) active water level gauging stations as listed below :

1) Rainfall Gauging Station

	Station		Remarks
(1)	Dhaka (B.M.D) **	:	Auto recorder (1958-1983)
(2)	Narayanganj (B.M.D) *	:	Closed in 1979
(3)	Dhaka (BWDB, St. 9) **	:	Incorporated into Dhaka (B.M.D) in 1985
(4)	Joydebpur (BWDB, St. 17) *	:	
(5)	Savar (BWDB, St. 31) *	:	
(6)	Narsindi (BWDB, St. 76) *	:	
(7)	Bancharampur (BWDB, St.351)*	:	
(8)	Daudkandi (BWDB, St.357)*	:	
(9)	Munshiganj (BWDB, St.365)*	:	
(10)	Narayanganj (BWDB, St.368)*	:	Closed in 1977
(11)	Nawabganj (BWDB, St.412)*	:	

Notes; 1)* : Manual
2)** : Manual and automatic rain gauge

The period of gauging and available data at each gauging station is shown in Table D.2.

There were only two automatic rain gauges in the study area, but they have not been used since 1984.

The others are all measured manually once a day at 9:00 A.M.

2) Water Level Gauging Station

(1)	Pubali	(BWDB St. 7	:	Balu River)
(2)	Demra	(BWDB St. 7.5	:	Balu River)
(3)	Nayarhat	(BWDB St. 14.5	:	Bansi River)
(4)*	Mill Barak	(BWDB St. 42	:	Buriganga River)
(5)	Hariharpara	(BWDB St. 43	:	Buriganga River)
(6)	Savar	(BWDB St. 69	:	Bansi River)
(7)	Kalatia	(BWDB St. 70	:	Dhaleswari River)
(8)	Kalagachia	(BWDB St. 71	:	Dhaleswari River)
(9)	Rekabi Bazar	(BWDB St. 71A	:	Dhaleswari River)
(10)	Demra	(BWDB St. 179	:	Lakhya River)
(11)	Narayanganj	(BWDB St. 180	:	Lakhya River)
(12)	Meghna Ferry Ghat	(BWDB St. 275.5	:	Surma-Meghna River)
(13)	Tongi	(BWDB St. 299	:	Tongi Khal)
(14)	Mirpur	(BWDB St. 302	:	Turag River)

Notes; 1) * : Autometic water level gauging station

2) : Narayanganj data was collected as the supplemental data in this study.

3) : Observation of Narayanganj (St. 180) had been conducted by BWDB until 1976. It has been conducted by BIWTA since 1977.

There is only one automatic gauging station at Mill Barak. The others are measured manually five times daily at 6:00, 9:00, 12:00, 15:00, 18:00. Period of gauging and available data at each station is shown in Table D.3.

The water level data of Narayanganj (St. 180) contains some inconsistency during the transition period from BWDB to BIWTA, though the consistency can be observed for the annual maximum water level data. Hence, reliability of its data is seemed to be less than the other data a little.

4.2 Features of Storm Rainfall

In the master plan, probable storm rainfall was calculated. The pump drainage plans including retarding ponds were formulated by using two days consecutive rainfall with five year return period with typical design hyetograph.

Furthermore, rainfall intensity and duration curves were formulated for various return periods. The drainage channels and culverts were planned by using the curve with 5-year return period.

Finally, areal reduction curves for converting point rainfall to basin mean rainfall were made.

Above results are also applied to this study.

4.2.1 Probable Storm Rainfall

Probable storm rainfall was calculated by the Gumble-Chow's method by using the maximum one day, two day, five day and one month rainfall as shown in Table D.4 to Table D.7 in the master plan stage.

Before conducting the frequency analysis, correlation of the rainfall data between Dhaka (B.M.D.), Joydebpur (BWDB st. 17), Savar (BWDB st. 31) and Narayanganj (B.M.D.) were studied for two day consecutive rainfall which is the most dominant rainfall of causing the internal floods of Dhaka area as described in the 1987 JICA Study. As a result, no correlation could be found between above stations.

Table D.8 shows the results of the frequency analysis.

As shown in this table, probable rainfalls of above four stations are almost same for one day and two day rainfall of two year and five year return period.

For this reason, probable rainfall in Dhaka (B.M.D.) of one day and two day rainfall of two year and five year return period can also be applied to Savar, Tongi and Narayanganj.

Furthermore, the difference in probable rainfall at Dhaka (B.M.D.) between this study and the 1987 JICA study of one day and two day rainfall of two year and five year return period is compared as shown below :

PROBABLE RAINFALL AT DHAKA (B.M.D)

(Unit : mm)

Duration	Return Period	This Study	1987 JICA Study
1 day	2 Year	137	135
	5 Year	184	192
2 day	2 Year	184	183
	5 Year	239	245

As shown above, probable rainfalls are almost same between the two studies.

Hence, above values of the 1987 JICA Study are also applicable. Furthermore, the 1987 JICA Study's values of five year return period are safer values than those of this study.

The typical rainfall pattern of one day rainfall of Dhaka (B.M.D.) was found to be six hours consecutive rainfall with peak rainfall intensity in the centre part. The design hyetograph for pump drainage plan was determined as shown in Fig. D.3 by using the design rainfall of two days consecutive rainfall with a 5-year return period.

For calculating the rainfall runoff, rational formula was applied.

Above design rainfall, design hyetograph and rational formula are to be also applied in this study.

4.2.2 Rainfall Intensity and duration

Fig. D.4 shows the rainfall intensity duration curves adopted in the master plan stage. The curves up to 120 minutes were made by conducting frequency analysis for the storm rainfall with short durations in the 1987 JICA study. The curves between 120 minutes and 24 hours were made in the master plan stage.

Drainage channels and culverts were designed by using the above rainfall intensity curve with a 5-year return period. It is able to express the curve as follows ;

$i = 9005 / (t + 50)$ for $t \leq 2.0$ hr

$i = 12437 / (t + 115)$ for $2.0 \text{ hr} \leq t \leq 24.0$ hr

Where, i = rainfall intensity (mm/hr)

t = duration (min)

Rainfall runoff was calculated by rational formula.

Above rainfall intensity and rational formula are to be also applied to this study.

4.2.3 Areal Reduction of Point Rainfall

In order to convert the design point rainfall of Dhaka (B.M.D.) to the design basin mean rainfall of sub-catchments in the drainage areas, areal reduction curves were made in the master plan stage as shown in Fig. D.5.

These curves are also to be applied in this study.

4.3 Features of Flood Water Level

In the master plan stage, flood mitigation plan was formulated using the higher value of 100-year probable flood water level or 1988 Floods' flood water level as the recorded maximum floods of 1988 Floods was estimated to be 70-year return period.

In this section, features of major floods and probable flood water level are described.

4.3.1 Features of Major Flood

1) Historical Floods

Major floods recorded in the Dhaka Metropolitan area occured in 1954, 1955, 1970, 1974, 1980, 1987 and 1988.

The maximum water levels at Mill Barak (St.42) and Demra (St.7.5) and Savar (St. 69) during the major floods are listed as follows :

ANNUAL MAXIMUM DAILY WATER LEVEL

(Unit : PWD in m)

Flood Year	Demra (St. 7.5)	Mill Barak (St. 42)	Savar (St.69)
1954	---	7.02	8.17
1955	---	7.05	8.26
1958	---	6.41	----
1970	6.24	6.47	7.99
1974	6.58	6.57	7.80
1980	6.23	6.39	----
1984	6.33	6.00	7.58
1987	6.46	6.60	8.30
1988	7.10	7.54	9.68

Note :

1) The above water levels of Mill Barak (St.42) and Demra (St.7.5) are revised by the results of check survey conducted in the 1987 JICA study (see Table D.9).

Fig. D.6 shows the estimated flow directions of 1970, 1974, 1980, 1984, 1987 and 1988 Floods by using the recorded flood water level.

According to these figures, the flow directions around the study area are always west to east for the Tongi Khal and the Dhaleswari River and north to south for the Balu River, the Lakhya River and the Buriganga River.

2) 1988 Floods

The 1988 Floods was the biggest floods among the recorded floods.

This was caused not only by the abnormally heavy and intensive rainfall in the upper catchment areas of the Ganges and the Brahmaputra Rivers in Himalayas during the end of August and the beginning of September, but also by the high backwater stage of the Meghna River which coincided the floods.

Fig. D.7 and Fig. D.8 shows the monthly rainfall and maximum water level in 1988. Fig. D.9 and Fig. D.10 shows the daily rainfall and maximum water level during

August and September. The monthly rainfall amount of August and September of 1988 in and around Dhaka area was 2/3 of annual average.

Considering these, 1988 Floods can be characterized as follows :

(1) The contribution of the rainfall of Dhaka area to the 1988 Floods was small.

(2) Sharp hydrographs in the north-western part and gentle hydrographs in the east and south parts coincide with the fact that the 1988 Floods came from the direction of the Brahmaputra-Jamuna River.

4.3.2 Probable Flood Water Levels

Probable flood water levels in and around the study area are revised by using the supplemental water level data of Narayanganj (BWDB St. 180).

The annual maximum water levels of the water level gauging stations in and around the study area is shown in Table D.9.

In order to estimate an accurate water level of large return period like 100 years, it is necessary to use the data with long duration including the 1988 Floods.

Gauging stations satisfying with the above conditions are listed as follows :

1)	Mill Barak (St.42)	:	37 years data
2)	Savar (St. 69)	:	33 years data
3)	Demra (St. 7.5)	:	35 years data by combining Demra (St. 7.5 and Demra (St. 179) using their correlation.
4)	Narayanganj (St. 180)	:	35 years

As the reliability of Narayanganj data seems to be less than the other data (refer to 4.1 (2)), data of Mill Barak (St. 42), Savar (St. 69) and Demra (St. 7.5) are used in conducting frequency analysis.

Before conducting frequency analysis, correlations between the water level data of Mill Barak (St. 42), Savar (St. 69) and Demra (St. 7.5) with other data are checked by using the results of the master plan stage. Fig. D.11 shows the correlation. They are also listed as follows :

CORRELATION OF WATER LEVEL GAUGING STATIONS

Station (X) Station (Y)	Mill Barak (St. 42)	Savar (St. 69)	Demra (St.7.5)
Mirpur (St. 302)	Y = 1.15 x +0.344	-----	----
Tongi (St. 299)	Y = 1.04 x +0.267	-----	----
Hariharpara (St. 43)	Y = 0.848 x +0.543	-----	----
Nayarhat (st. 14.5)	---	Y = 1.105 x -0.432	----
Kalatia (St. 70)	---	Y = 0.867 x +0.367	----
Demra (St. 179)	----		Y = 0.943 x +0.267
Narayanganj (St. 180)	----		Y = 0.848 x +0.561
Pubali (St. 7)	----		Y = 1.066 x -0.130
Rekabi Bazar (St. 71A)	----		Y = 0.834 x +0.549
Kalagachia (St. 71)	----		Y = 0.752 x +0.896

As for the probable water levels, frequency analysis is conducted for Mill Barak (St.42), Savar (St. 69) and Demra (St. 7.5) by the Gumbel-Chow's method and other probable water levels are calculated by using the correlation described above.

The results are same as that of the master plan stage except Narayanganj (st. 180). They are shown in Table D.10.

By using this table, return periods of the 1987 Floods and the 1988 Floods are estimated as follows ;

RETURN PERIODS OF THE 1987 FLOODS AND THE 1988 FLOODS

Station	1987 Floods	1988 Floods
Demra (St. 7.5)	8-Year	50-Year
Mill Barak (St. 42)	10-Year	70-Year
Savar (St. 69) 15-Year	200-Year	

5. Hydraulic Simulation for Drainage Area

In this chapter, hydraulic simulation for drainage area is described. The simulation is conducted by one dimensional unsteady flow model using Mike 11 software.

5.1 Objective of Hydraulic Simulation

As described in Supporting Report E " Flood Mitigation and Drainage Plan", drainage facilities of drainage channel, pump station and retarding ponds are planned by using simple methods as follows ;

a) Drainage Channel : channel design is conducted by using the design discharge given by rainfall runoff calculation. Rainfall runoff calculation is conducted by the rational formula using rainfall intensity curve of 5-year return period. Channel size is determined mainly by conducting uniform flow calculation.

b) Pump Station : pump capacity is determined by mass curve analysis so as to discharge out the total rainfall runoff amount of 2 day consecutive rainfall with a 5 year return period into the drainage area within 2 days.

c) Retarding Pond : retarding pond capacity is determined by mass curve analysis so as to storage the maximum difference between the accumulated amount of rainfall runoff and that of pump discharge during the 2 days.

Due to the flat topography and not simple network of the drainage system, it is necessary to check the validity of the above design by unsteady flow calculation.

Especially, the retarding effect can be checked clearly by the hydraulic simulation.

5.2 Hydraulic Simulation for DND

As the topography of DND is very flat and the drainage network of DND is like braided system, the priority of necessity of checking the validity of the design of simple method is very high.

1) River Network

Fig. D.12 shows the river network of DND area for hydraulic simulation.

The network is composed of drainage channels, retarding areas and pump stations which are planned by Drainage Improvement Plan using simple design method as described in sub-section 5.1.

All the cross sections of the topographic survey data of about 250-500 m interval are used to set up the network.

Rainfall runoff of sub-catchments are imputed into the network as boundary discharge or lateral inflow.

Fig. D.13 shows the drainage channels and sub-catchments of the DND area corresponding to Fig. D.12.

2) Boundary Conditions

Boundary conditions relating to the above network and simulation case are consist of following items ;

a) Rainfall Runoffs of Sub-Catchments

Rainfall runoffs of sub-catchments are calculated by the rational formula using the design hyetograph. The design hyetograph are created for each sub-catchment by each time of concentration as same as the design hyetograph shown in Fig. D.3.

b) Water Level of the Lakhya River

Water level of the Lakhya River is LWL for gravity flow condition and HWL for pump operating condition.

3) Cases of Simulation

Cases of simulation for DND area are as follows :

CASES OF SIMULATION

Simulation Case		Water Level of the Lakhya River (PWD m)	Pump Capacity (m3/s)
Case 1-1	Without retarding areas and without pump stations	LWL : KN-1 side : 3.00 Kn-4 side : 3.00	-
Case 1-2	Without retarding areas and without pump stations	HWL : KN-1 side : 5.75 KN-4 side : 5.65	KN-1 side:14.5 KN-4 side:50.2
Case 2-1	Without retarding areas and without pump stations	LWL : KN-1 side : 3.00 KN-4 side : 3.00	-
Case 2-2	Without retarding areas and without pump stations	HWL : KN-1 side : 5.75 KN-4 side : 5.65	KN-1 side:14.5 KN-4 side:50.2

4) Results of Simulation

Fig. D.14, Fig. D.15 and Fig. D.16 show the profiles of simulated peak water level, water level hydrographs and discharge hydrographs of case 1-1, 1-2, 2-1 and 2-2.

As shown in Fig, D.14, the peak water levels of the cases of without retarding ponds (case 1-1 and case 1-2) are higher than the design bank and those of the cases of with retarding ponds (case 2-1 and case 2-2) are lower than the design bank. Hence, it can be said that the simple design method using rational formula, uniform flow calculation and mass curve calculation is adequate for designing drainage facilities such as drainage channels, pump stations and retarding area of the DND area.

But, as the differences between the peak water levels and the design bank heights of case 2-1 and case 2-2 are bigger than the design allowance in several ten centimeters, it is possible to modify slightly, the sizes of drainage channels, pump stations and retarding ponds to adjust the above difference to the design allowance by using this one-dimensional unsteady flow model.

5.3 Hydraulic Simulation of Greater Dhaka East

There are three big khals in the Greater Dhaka East. They are the Boalia Khal, the Jamair Khal and the Begunbari Khal. As the khal systems of the Jamair Khal and the Begunbari Khal are not symple, it is necessary to check the design of drainage channels, pump stations and retarding ponds by simple design method as described in sub-section 5.1 by one-dimensional flow model of MIKE 11 for these khals.

5.3.1 Sub-drainage Zones

The sub-drainage zones of the Jamair Khal and the Begunbari Khal are determined as follows by "Flood Mitigation and Drainage Plan".

Jamair Khal	:	Sub-drainage zone DC-2
Begunbari Khal	:	Sub-drainage zone DC-3 (northern half)
		Sub-drainage zone DC-4 (southern half)

These sub-drainage zones as well as their drainage channels and sub-catchments are shown in Fig. D.17.

5.3.2 Hydraulic Simulation of Sub-drainage Zone DC-2

1) River network

Fig. D.17 shows the rive network and proposed simulation model of sub-drainage zone DC-2.

Sizes of drainage channels, pump stations and retarding areas are given by the simple design method all the cross sections of the topographic survey data of about 250-500 interval are used to set up the network.

2) Boundary conditions

Rainfall run-off of sub-catchments are imputed into the network as boundary discharge or lateral inflow.

Water level of the Balu River is LWL for gravity flow condition and HWL for pump operating condition.

3) Cases of Simulation

Simulation cases are for cases as shown below ;

CASES OF SIMULATION

Simulation Case		Water Level of the Balu River (PWD m)	Pump Capacity (m3/s)
Case 1-1	Without retarding areas and without pump stations	LWL : 3.00	-
Case 1-2	Without retarding areas and without pump stations	HWL : 6.15	54.6
Case 2-1	Without retarding areas and without pump stations	LWL : 3.00	-
Case 2-2	Without retarding areas and without pump stations	HWL : 6.15	54.6

4) Results of Simulation

Fig. D.18, Fig. D.19 and Fig. D.20 show the profiles of simulated peak water level, water level hydrographs and discharge hydrographs of case 1-1, 1-2, 2-1 and 2-2.

As shown in Fig, D.18, the peak water levels of the cases of without retarding areas case 1-1 and case 1-2 are higher than the design bank and those of the cases of with retarding areas case 2-1 and case 2-2) are lower than the design bank with a little bigger allowance in the downstream portion than the design allowance.

Hence, the simple design method can be said appropriate.

Furthermore, slightly modification of the sizes of drainage channels, pump stations and retarding areas to adjust the above allowance in downstream portion to the design allowance can be done by using this one-dimensional unsteady flow model.

5.3.3 Hydraulic Simulation of Sub-drainage Zone DC-3

1) River Network

Fig. D.21 shows the rive network and proposed simulation model of sub-drainage zone DC-3

2) Boundary Conditions

Boundary conditions are given by the same way as DC-2.

3) Cases of Simulation

Simulation cases as shown below ;

CASES OF SIMULATION

Simulation Case		Water Level of the Balu River (PWD m)	Pump Capacity (m3/s)
Case 1-1	Without retarding areas and without pump stations	LWL : 3.00	-
Case 1-2	Without retarding areas and without pump stations	HWL : 6.05	53.10
Case 2-1	Without retarding areas and without pump stations	LWL : 3.00	-
Case 2-2	Without retarding areas and without pump stations	HWL : 6.05	53.10

4) Results of Simulation

Fig. D.22, Fig. D.23 and Fig. D.24 show the profiles of simulated peak water level, water level hydrographs and discharge hydrographs of case 1-1, 1-2, 2-1 and 2-2.

As shown in Fig, D.22, the peak water levels of the cases of without retarding areas case 1-1 and case 1-2 are higher than the design bank and those of the cases of with retarding areas case 2-1 and case 2-2) are lower than the design bank with a little bigger allowance in the downstream portion than the design allowance.

Hence, the simple design method can be said appropriate.

Furthermore, slightly modification of the sizes of drainage channels, pump stations and retarding areas to adjust the above allowance in downstream portion to the design allowance can be done by using this one-dimensional unsteady flow model.

5.3.4 Hydraulic Simulation of Sub-drainage Zone DC-4

1) River network

Fig. D.25 shows the rive network and proposed simulation model of sub-drainage zone DC-4

2) Boundary Conditions

Boundary conditions are given by the same way as DC-2.

3) Cases of Simulation

Simulation cases as shown below ;

CASES OF SIMULATION

Simulation Case		Water Level of the Balu River (PWD m)	Pump Capacity (m3/s)
Case 1-1	Without retarding areas and without pump stations	LWL : 3.00	-
Case 1-2	Without retarding areas and without pump stations	HWL : 6.00	47.2
Case 2-1	Without retarding areas and without pump stations	LWL : 3.00	-
Case 2-2	Without retarding areas and without pump stations	HWL : 6.00	47.2d

4) Results of Simulation

Fig. D.26, Fig. D.27 and Fig. D.28 show the profiles of simulated peak water level, water level hydrographs and discharge hydrographs of case 1-1, 1-2, 2-1 and 2-2.

As shown in Fig, D.26, the peak water levels of the cases of without retarding areas case 1-1 and case 1-2 are higher than the design bank and those of the cases of with retarding areas case 2-1 and case 2-2) are lower than the design bank with a little bigger allowance in the downstream portion than the design allowance.

Hence, the simple design method can be said appropriate.

Furthermore, slightly modification of the sizes of drainage channels, pump stations and retarding areas to adjust the above allowance in downstream portion to the design allowance can be done by using this one-dimensional unsteady flow model.

TABLE D.1 CLIMATE CONDITIONS IN THE STUDY AREA

MONTH	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	oct	Nov	Dec
Temperature, °c High (Extreme)	34.2	36.6	40.6	42.3	40.6	38.4	35.2	35.9	35.3	38.8	33.3	31.2
Low (Extreme)	5.6	4.5	10.4	15.6	18.4	20.4	21.7	21.0	22.0	10.4	10.6	6.7
Avg.	18.8	21.5	26.1	28.7	28.9	28.7	28.7	28.7	28.7	27.4	23.6	19.8
Relative Humidity, Percent	70	66	63	71	79	86	87	86	86	81	75	74
Evaporation, millimeters	104	79	81	77	78	83	87	130	118	106	75	105
Days of Rain, per month	1	2	4	8	14	19	22	22	16	9	2	1
Average Rainfall, millimeters	6.5	20.2	52.3	124.0	283.0	398.2	391.4	328.0	264.0	160.0	25.3	7.4
Wind Velocities, Knots (Knot=1,852 km/hr)	2	2	3	5	5	4	4	4	3	2	1	1

Data : 1) Bangladesh Meteorological Department (1953-1985)

2) Evaporation , H.R. Laboratory (Dhaka) No. E-10 (1978-1979)

Source : JICA; Study on Storm Water Drainage System Improvement Project in Dhaka City, 1987

TABLE D.2 LIST OF RAINFALL GAUGING STATIONS AND AVAILABLE DATA

STATION NAME	AGENCY	STAION NO.		LOCATION	DATE OF ESTAB-LISHMENT	MEASUREMENT	DATA	REMARKS
1) DHAKA	B.M.D.	-	Latitude : Longitude :	23 deg. 46.0 min. N 90 deg. 23.0 min. E	1949	Manual Auto	1953 - 1990	Auto recorder(1957 - 1983)
2) NARAYANGANJ	B.M.D.	-	Latitude : Longitude :	23 deg. 37.0 min. N 90 deg. 30 .0min. E	1867	Manual	1948 - 1979	Closed in 1979
3) DHAKA	BWDB	9	Latitude : Longitude :	23 deg. 47.2 min. N 90 deg. 24.2 min. E	08. 07. 1960	Manual Auto	1957 - 1990	Incorporated into Dhaka(B.M.D.) in 1985
4) JOYDEBPUR	BWDB	17	Latitude : Longitude :	24 deg. 00.0 min. N 90 deg. 25.0 min. E	11. 03. 1961	Manual	1961 - 1990	
5) SAVAR	BWDB	31	Latitude : Longitude :	24 deg. 01.0 min. N 90 deg. 11.0 min. E	23. 11. 1961	Manual	1962 - 1990	
6) NARSINDI	BWDB	76	Latitude : Longitude :	23 deg. 57.3 min. N 90 deg. 44.5 min. E	06. 03. 1961	Manual	1961 - 1990	
7) BANCHARAMPUR	BWDB	351	Latitude : Longitude :	23 deg. 44.5 min. N 90 deg. 45.7 min. E	02. 03. 1961	Manual	1961 - 1990	
8) DAUDKANDI	BWDB	357	Latitude : Longitude :	23 deg. 32.0 min. N 90 deg. 43.0 min. E	27. 06. 1961	Manual	1983 - 1990	
9) MUNSHIGANJ	BWDB	365	Latitude : Longitude :	23 deg. 33.1 min. N 90 deg. 32.2 min. E	25. 11. 1960	Manual	1963 - 1990	
10) NARAYANGANJ	BWDB	368	Latitude : Longitude :	23 deg. 36.8 min. N 90 deg. 30.2 min. E	-	Manual	1961 - 1977	Closed in 1977
11) NAWABGANJ	BWDB	412	Latitude : Longitude :	23 deg. 39.5 min. N 90 deg. 10.0 min. E	13. 03. 1961	Manual	1965 - 1990	

TABLE D.3 LIST OF WATER LEVEL GAUGING STATIONS AND AVAILABLE DATA

STATION NAME	AGENCY	STAION NO.	RIVER	LOCATION	DATE OF ESTAB-LISHMENT	MEASUREMENT	DATA OF WATER LEVEL	DATA OF DISCHARGE	DATA OF RATING CURVE
1) PUBAIL	BWDB	7	Balu	Latitude : 23 deg. 56.5 min. N Longitude : 90 deg. 29.8 min. E	26. 6. 1945	Manual	1945 - 1990	-	-
2) DEMRA	BWDB	7.5	Balu	Latitude : 23 deg. 44.0 min. N Longitude : 90 deg. 30.0 min. E	21. 10. 1964	Manual	1962 - 1990	1979 - 1989	1979 - 1987
3) NAYARHAT	BWDB	14.5	Bansi	Latitude : 23 deg. 54.7 min. N Longitude : 90 deg. 14.0 min. E	11. 06. 1963	Manual	1964 - 1988	1979 - 1989	1977 - 1989
4) MILL BARAK	BWDB	42	Buriganga	Latitude : 23 deg. 41.9 min. N Longitude : 90 deg. 25.3 min. E	10. 10. 1906	Manual Auto	1945 - 1990	-	-
5) HARIHARPARA	BWDB	43	Buriganga	Latitude : 23 deg. 38.0 min. N Longitude : 90 deg. 28.5 min. E	04. 06. 1945	Manual	1945 - 1990	-	-
6) SAVAR	BWDB	69	Dhaleswari	Latitude : 24 deg. 01.0 min. N Longitude : 90 deg. 11.o min. E	13. 07. 1945	Manual	1945 - 1990	-	-
7) KALATIA	BWDB	70	Dhaleswari	Latitude : 23 deg. 42.9 min. N Longitude : 90 deg. 15.9 min. E	01. 10. 1958	Manual	1968 - 1990	-	-
8) KALAGACHIA	BWDB	71	Dhaleswari	Latitude : 23 deg. 34.7 min. N Longitude : 90 deg. 32.7 min. E	15. 06. 1945	Manual	1977 - 1990	-	-
9) REKABI BAZAR	BWDB	71A	Dhaleswari	Latitude : 23 deg. 34.4 min. N Longitude : 90 deg. 29.7 min. E	16. 12. 1965	Manual	1968 - 1990	-	-
10) DEMRA	BWDB	179	Lakhya	Latitude : 23 deg. 44.0 min. N Longitude : 90 deg. 31.5 min. E	18. 06. 1945	Manual	1952 - 1990	-	1977 - 1989
11) NARAYANGANJ	BWDB BIWTA	180	Lakhya	Latitude : 23 deg. 38.1 min. N 90 deg. 38.8 min. E	26. 06. 1946	Manual	1947 - 1990	-	-
12) MEGHNA FERRY GHAT	BWDB	275.5	Surma-Meghna	Latitude : 23 deg. 36.2 min. N Longitude : 90 deg. 37.5 min. E	25. 09. 1965	Manual	1968 - 1990	-	-
13) TONGI	BWDB	299	Tongi Khal	Latitude : 23 deg. 52.8 min. N Longitude : 90 deg. 24.2 min. E	25. 03. 1960	Manual	1960 - 1990	-	-
14) MIRPUR	BWDB	302	Turag	Latitude : 23 deg. 47.3 min. N Longitude : 90 deg. 20.3 min. E	-	Manual	1953 - 1990	1983 - 1989	1977 - 1989

TABLE D.4 ANNUAL MAXIMUM DAILY RAINFALL

(unit : mm)

NO.	STATION	DHAKA	NARAYANGANJ	DHAKA	JOYDEBPUR	SAVAR	NARSINDI	SANCHARAMPUR	DAUDKANDI	MUNSHIGANJ	NARAYANGANJ	NAWABGONJ
		B.M.D.	B.M.D	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB
				STA. NO.9	STA. NO.17	STA. NO.31	STA. NO.76	STA. NO.351	STA. NO.357	STA. NO.365	STA. NO.368	STA. NO.412
	DATA	1953-1990	1948-1979	1957-1990	1961-1990	1962-1990	1961-1990	1961-1990	1983-1990	1963-1990	1961-1977	1965-1990
NO.	YEAR											
1	1948		-									
2	1949		119									
3	1950		183									
4	1951	-	149									
5	1952		133									
6	1953	90	-									
7	1954	147	-									
8	1955	115	86									
9	1956	326	149									
10	1957	73	62	72								
11	1958	137	158	113								
12	1959	125	134	120								
13	1960	141	160	112								
14	1961	185	202	154	140		168	137			116	
15	1962	116	87	81	107	246	110	-			-	
16	1963	189	197	207	127	87	146	171		73	163	
17	1964	114	231	144	161	165	136	-		-	-	
18	1965	177	-	222	173	179	122	118		112	109	127
19	1966	257	216	283	137	122	186	164		83	216	179
20	1967	125	137	98	140	142	126	146		109	118	96
21	1968	145	135	137	177	163	101	97		144	135	180
22	1969	86	252	76	69	93	157	244		109	91	72
23	1970	152	81	113	112	82	192	90		137	81	108
24	1971	251	106	196	126	88	202	135		127	-	128
25	1972	231	167	165	77	114	116	64		102	-	224
26	1973	168	170	216	208	133	144	182		127	115	129
27	1974	-	-	107	165	136	181	108		127	166	109
28	1975	143	132	158	165	235	122	179		127	132	105
29	1976	163	105	158	107	162	186	121		136	147	-
30	1977	100	193	149	104	126	123	90		141	-	53
31	1978	128	-	134	184	165	226	181		127		99
32	1979	108	-	127	229	187	157	184		127		61
33	1980	91		91	95	-	164	55		-		79
34	1981	83		81	125	114	285	136		82		86
35	1982	146		146	129	165	106	65		239		-
36	1983	128		133	193	146	199	188	125	174		179
37	1984	150		151	112	184	181	161	107	161		78
38	1985	92		92	83	107	164	61	94	113		81
39	1986	176		176	167	109	147	212	104	206		-
40	1987	138		138	153	99	120	174	155	69		79
41	1988	135		135	155	-	122	189	119	108		-
42	1989	118		118	129	102	89	73	125	84		69
43	1990	-		-	-	-	-	-	-	-		-
	AVERAGE	146	150	139	140	140	154	138	118	126	132	111

TABLE D.5 ANNUAL MAXIMUM TWO DAY RAINFALL

(unit : mm)

NO.	STATION	DHAKA	NARAYANGANJ	DHAKA	JOYDEBPUR	SAVAR	NARSINDI	BANCHARAMPUR	DAUDKANDI	MUNSHIGANJ	NARAYANGANJ	NAWABGONJ
		B.M.D.	B.M.D	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB
				STA. NO.9	STA. NO.17	STA. NO.31	STA. NO.76	STA. NO.351	STA. NO.357	STA. NO.365	STA. NO.368	STA. NO.412
	DATA	1953-1990	1948-1979	1957-1990	1961-1990	1962-1990	1961-1990	1961-1990	1983-1990	1963-1990	1961-1977	1965-1990
NO.	YEAR											
1	1948		-									
2	1949		143									
3	1950		233									
4	1951		165									
5	1952		172									
6	1953	127	-									
7	1954	255	-									
8	1955	120	124									
9	1956	346	179									
10	1957	98	97	102								
11	1958	140	166	176								
12	1959	179	171	178								
13	1960	223	238	151								
14	1961	185	202	189	152		205	207			177	
15	1962	141	130	123	156	297	133	-			-	
16	1963	257	307	278	131	110	181	184		108	187	
17	1964	206	266	195	254	196	244	-		-	-	
18	1965	181	-	225	221	184	225	118		154	133	129
19	1966	270	302	339	229	167	211	251		100	302	202
20	1967	147	207	141	231	161	189	232		150	207	96
21	1968	240	263	235	210	197	168	172		259	263	183
22	1969	104	255	122	107	117	196	258		182	165	92
23	1970	262	132	185	147	118	232	134		164	133	172
24	1971	328	188	272	162	139	319	135		229	-	166
25	1972	251	183	215	117	145	191	98		178	-	292
26	1973	177	204	224	221	133	255	213		203	136	213
27	1974	-	-	183	182	136	237	147		229	170	154
28	1975	212	246	257	264	371	227	353		198	246	112
29	1976	263	194	275	199	250	310	168		224	218	-
30	1977	133	228	155	115	150	148	109		208	-	93
31	1978	191	-	185	267	199	230	186		168		160
32	1979	166	-	168	330	268	191	212		218		79
33	1980	125		125	132	-	203	86		-		109
34	1981	148		148	201	160	288	170		123		122
35	1982	167		167	181	208	182	96		301		-
36	1983	194		199	290	249	362	321	242	248		189
37	1984	200		201	160	261	247	234	180	219		105
38	1985	132		105	142	159	217	95	151	117		142
39	1986	321		321	271	164	234	270	196	277		-
40	1987	172		172	230	168	193	209	201	107		119
41	1988	175		175	283	-	200	301	138	155		-
42	1989	151		151	160	155	112	119	127	145		107
43	1990	-		-	-	-	-	-	-	-		-
	AVERAGE	194	200	192	198	187	218	188	178	187	193	145

TABLE D.6 ANNUL MAXIMUM FIVE DAY RAINFALL

(unit : mm)

	STATION	DHAKA	NARAYANGANJ	DHAKA	JOYDEBPUR	SAVAR	NARSINDI	BANCHARAMPUR	DAUDKANDI	MUNSHIGANJ	NARAYANGANJ	NAWABGONJ
		B.M.D.	B.M.D	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB
				STA. NO.9	STA. NO.17	STA. NO.31	STA. NO.76	STA. NO.351	STA. NO.357	STA. NO.365	STA. NO.368	STA. NO.412
	DATA	1953-1990	1946-1979	1957-1990	1961-1990	1962-1990	1961-1990	1961-1990	1983-1990	1963-1990	1961-1977	1965-1990
NO.	YEAR											
1	1948		-									
2	1949		224									
3	1950		295									
4	1951		198									
5	1952		183									
6	1953	150	-									
7	1954	323	-									
8	1955	181	182									
9	1956	430	259									
10	1957	184	191	175								
11	1958	170	166	200								
12	1959	309	298	297								
13	1960	331	257	188								
14	1961	317	264	226	283		264	299			264	
15	1962	164	160	164	223	297	204	-			-	
16	1963	327	350	325	144	188	234	338		188	197	
17	1964	241	299	231	295	238	315	-		-	-	
18	1965	219	-	239	307	277	272	192		241	203	147
19	1966	288	343	360	279	190	347	389		212	327	244
20	1967	250	292	223	326	170	329	317		223	292	179
21	1968	379	343	325	263	289	314	345		377	387	301
22	1969	199	297	200	192	173	361	313		227	240	126
23	1970	303	163	248	254	157	347	229		269	142	204
24	1971	355	331	296	300	273	616	180		381	-	236
25	1972	314	215	263	163	202	283	205		394	-	377
26	1973	205	252	271	269	154	420	344		381	168	225
27	1974	-	-	236	209	174	285	211		508	220	202
28	1975	401	429	445	475	507	331	576		315	428	230
29	1976	436	318	447	368	358	410	305		288	380	-
30	1977	175	308	198	189	192	264	123		273	-	160
31	1978	216	-	244	288	283	324	311		338		231
32	1979	234	-	180	500	446	239	222		396		142
33	1980	259		259	215	-	307	140		-		188
34	1981	168		168	309	185	349	278		174		175
35	1982	193		193	209	254	361	105		338		-
36	1983	250		255	363	286	450	419	407	284		249
37	1984	296		296	315	377	491	452	330	319		146
38	1985	169		169	302	262	329	130	193	147		170
39	1986	401		401	331	255	361	355	236	402		-
40	1987	234		234	406	203	272	390	290	168		151
41	1988	301		301	413	-	369	399	243	191		-
42	1989	152		152	178	208	195	129	128	207		175
43	1990	-		-	-	-	-	-	-	-		-
	AVERAGE	265	265	255	289	254	333	285	261	290	271	203

TABLE D.7 ANNUAL MAXIMUM MONTHLY RAINFALL

(unit : mm)

NO.	STATION	DHAKA	NARAYANGANJ	DHAKA	JOYDEBPUR	SAVAR	NARSINDI	BANCHARAMPUR	DAUDKANDI	MUNSHIGANJ	NARAYANGANJ	NAWABGONJ
		B.M.D.	B.M.D	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB
				STA. NO.9	STA. NO.17	STA. NO.31	STA. NO.76	STA. NO.351	STA. NO.357	STA. NO.365	STA. NO.368	STA. NO.412
	DATA	1953-1990	1948-1979	1957-1990	1961-1990	1962-1990	1961-1990	1961-1990	1983-1990	1963-1990	1961-1977	1965-1990
NO.	YEAR											
1	1948		-									
2	1949		414									
3	1950		711									
4	1951	-	484									
5	1952		438									
6	1953	392	552									
7	1954	810	-									
8	1955	502	340									
9	1956	690	387									
10	1957	487	415	349								
11	1958	267	374	280								
12	1959	568	605	544								
13	1960	655	533	489								
14	1961	856	489	495	-		-	537			-	
15	1962	395	298	430	393	-	477	486			-	
16	1963	621	418	678	355	-	573	711		-	-	
17	1964	629	451	673	512	554	912	-		-	-	
18	1965	480	-	442	592	575	705	484		-	-	416
19	1966	496	479	607	490	391	581	671		414	501	439
20	1967	504	525	476	550	395	563	504		431	509	304
21	1968	590	502	449	565	537	588	451		565	501	471
22	1969	540	428	494	498	628	754	489		459	434	448
23	1970	496	285	414	439	403	601	355		396	304	365
24	1971	550	644	465	629	595	911	384		930	-	471
25	1972	380	356	469	274	357	589	295		808	-	491
26	1973	621	521	618	536	444	875	524		953	-	462
27	1974	-	634	604	593	485	1046	604		1514	623	670
28	1975	559	627	625	634	647	490	608		876	655	399
29	1976	627	542	649	487	547	722	602		736	647	-
30	1977	381	539	593	385	392	504	290		526	-	422
31	1978	529	-	583	788	542	898	716		500		285
32	1979	525	-	437	685	707	635	299		632		196
33	1980	414		411	411	-	676	362		-		422
34	1981	411		320	485	-	672	446		334		392
35	1982	514		514	494	489	568	288		501		-
36	1983	408		434	639	401	705	552	-	611		344
37	1984	891		707	559	591	1065	773	963	567		378
38	1985	399		399	530	352	504	235	526	288		258
39	1986	687		687	498	477	590	558	422	596		-
40	1987	526		526	744	532	636	520	460	429		-
41	1988	580		579	716	-	692	1069	374	418		-
42	1989	347		347	484	-	332	211	362	329		-
43	1990	-		-	-	-	-	-	-	-		-
	AVERAGE	537	481	509	534	502	674	501	518	600	522	402

TABLE D.8 PROBABLE STORM RAINFALL

(Unit : mm)

DURATION	RAIN STATION	RETURN PERIOD (YEAR)					
		2	5	10	20	50	100
1 day	Dhaka (B.M.D.)	137	184	215	244	283	311
	Savar (BWDB Sta.31)	133	171	196	220	251	274
	Joydebpur (BWDB Sta. 17)	133	167	190	211	239	260
	Narayanganj (B.M.D.)	142	184	212	239	273	299
2 day	Dhaka (B.M.D.)	184	239	276	311	357	391
	Savar (BWDB Sta.31)	177	231	267	301	346	379
	Joydebpur (BWDB Sta. 17)	189	240	275	308	350	382
	Narayanganj (B.M.D.)	191	239	270	301	340	369
5 day	Dhaka (B.M.D.)	251	324	372	418	478	523
	Savar (BWDB Sta.31)	240	316	367	416	479	527
	Joydebpur (BWDB Sta. 17)	274	351	402	451	514	561
	Narayanganj (B.M.D.)	253	314	355	394	444	482
1 month	Dhaka (B.M.D.)	514	636	716	793	892	967
	Savar (BWDB Sta.31)	486	573	630	686	757	811
	Joydebpur (BWDB Sta. 17)	515	619	687	753	838	901
	Narayanganj (B.M.D.)	437	558	620	679	757	814

TABLE D.9 ANNUAL MAXIMUM WATER LEVEL

COMPARISON OF ANNUAL MAXIMUM WATER LEVEL RIVISED BY CHECH SURVEY

(UNIT :PWD in m)

NO.	STATION	PUBAIL	DEMRA	NAYARHAT	MILL BARAK	HARIHARPARA	SAVAR	KALATIA	KALAGACHIA	RAKABI BAZAR	DEMRA	NARAYANGANJ	MEGHNA FERRY GHAT	TONGI	MIRPUR
		BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB	BWDB
		STA. NO.7	STA. NO.7.5	STA. NO.14.5	STA. NO.42	STA.NO.43	STA. NO. 69	STA. NO.70	STA. NO. 71	STA. NO. 71A	STA. NO. 179	STA. NO.180	STA. NO.275.5	STA. NO.299	STA. NO. 302
	RIVER	BALU	BALU	BANGSHI	BURIGANGA	BURIGANGA	DHALESWARI	DHALESWARI	DHALESWARI	DHALESWARI	LAKHYA	LAKHYA	SURMA-MEGHNA	TONGI KHAL	TURAG
	DATA	1945-1990	1962-1990	1964-1990	1945-1990	1945-1990	1945-1990	1968-1990	1977-1990	1968-1990	1952-1990	1947-1990	1968-1990	1960-1990	1953-1990
NO.	YEAR														
1	1945	-			6.00	-	7.41								
2	1946	-			5.96	5.28	6.84								
3	1947	5.53			5.60	-	6.98					5.09			
4	1948	5.82			6.26	-	7.20					5.36			
5	1949	-			5.96	5.94	7.23					5.33			
6	1950	5.43			5.72	-	7.04					5.27			
7	1951	-			-	-	7.35					5.27			
8	1952	5.41			5.45	-	7.10				5.58	5.33			
9	1953	-			5.66	5.24	7.06				5.58	5.27			6.27
10	1954	6.65			7.02	6.22	8.17				6.52	6.04			7.64
11	1955	-			7.05	6.40	8.26				6.77	6.16			7.66
12	1956	6.19			5.64	4.82	6.83				5.73	5.24			6.03
13	1957	5.92			5.32	5.06	7.20				5.52	5.58			6.20
14	1958	6.54			6.41	-	-				5.97	5.46			7.17
15	1959	6.08			5.74	5.33	7.12				-	-			6.52
16	1960	6.17			6.06	5.53	7.57				-	-		6.40	6.62
17	1961	-			5.48	-	7.30				-	-		-	5.98
18	1962	6.92	6.29		-	-	-				-	5.94		7.27	7.57
19	1963	-	5.92		-	-	-				-	-		6.55	6.75
20	1964	-	6.40	8.16	-	-	-				-	-		7.00	7.17
21	1965	-	5.81	7.62	-	-	-				5.83	-		6.54	6.56
22	1966	-	6.24	8.00	-	-	-				6.30	-		6.78	6.98
23	1967	-	5.43	7.07	-	-	-				5.46	-		5.87	-
24	1968	-	6.08	8.03	6.30	5.85	7.69	6.84		5.75	6.09	5.90	5.68	6.70	6.76
25	1969	6.19	5.85	7.55	5.89	5.63	7.08	6.46		5.47	5.87	5.58	5.63	6.34	6.37
26	1970	6.74	6.24	8.69	6.47	6.04	7.99	7.10		5.85	-	-	5.87	7.11	7.17
27	1971	6.42	6.03	-	6.19	5.85	7.36	6.81		-	6.08	5.76	-	6.72	-
28	1972	5.64	5.40	6.97	5.26	5.01	6.66	6.07		5.00	5.44	5.12	5.11	5.81	5.74
29	1973	6.25	5.88	7.70	5.84	5.55	7.21	6.55		5.46	5.88	5.52	5.44	6.36	6.36
30	1974	6.95	6.58	8.44	6.57	6.34	7.80	7.12		6.07	6.60	6.23	6.19	7.10	7.09
31	1975	5.73	5.60	-	5.39	5.23	-	-		5.18	5.60	5.36	5.29	-	-
32	1976	5.64	5.47	6.44	5.13	4.98	6.31	5.98		-	5.53	5.17	5.32	-	-
33	1977	6.03	5.92	7.15	5.60	5.39	6.88	6.34	5.34	5.39	5.81	5.52	5.59	6.03	5.99
34	1978	-	-	6.48	5.22	5.05	6.29	5.83	5.03	-	5.45	5.22	-	5.56	5.51
35	1979	-	5.59	6.46	5.25	5.08	-	-	-	-	5.49	5.00	-	5.60	5.54
36	1980	6.66	6.23	8.58	6.39	-	-	7.21	-	5.61	-	6.03	-	6.99	7.20
37	1981	-	5.74	6.74	5.42	-	-	-	-	-	5.65	-	5.40	-	5.79
38	1982	-	6.00	6.34	-	-	-	-	-	-	5.35	5.20	5.19	6.02	5.41
39	1983	6.05	5.90	7.23	5.73	5.43	6.96	6.38	5.44	5.49	5.81	5.54	5.56	6.40	6.03
40	1984	6.35	6.33	8.12	6.00	5.72	7.58	7.11	5.91	5.74	6.04	5.77	5.73	7.10	6.63
41	1985	5.83	5.70	7.04	5.37	5.12	6.70	6.18	5.06	5.28	5.57	5.33	5.44	5.75	5.79
42	1986	5.70	5.25	6.77	4.96	4.82	6.69	6.20	4.65	4.97	5.14	5.03	5.03	5.50	5.43
43	1987	6.90	6.46	8.74	6.60	6.23	8.30	7.53	5.92	6.02	6.38	6.09	5.99	7.02	7.30
44	1988	7.29	7.10	9.90	7.54	7.17	9.68	8.91	5.97	6.43	-	6.63	6.55	7.96	8.39
45	1989	5.47	5.44	6.21	5.06	4.78	6.34	5.92	5.04	5.10	5.34	5.23	-	5.38	5.42
46	1990	-	-	-	-	-	-	-	-	-	-	5.23	-	-	-
	AVERAGE	6.16	5.96	7.52	5.88	5.54	7.28	6.70	5.37	5.55	5.81	5.52	5.59	6.46	6.52

Notes : 1) The above water levels of Mill Barak, Mirpur, Tongi and Demra(Sta. 7.5) are revised by the results of check survey conducted in 1987 JICA STUDY.

2) The aquations for the revision are as follows ;

Mill Barak : Y=X - 0.037
Mirpur : Y=X + 0.042
Tongi : Y=X + 0.122
Demra(7.5) : Y=X + 0.007

where, X : raw data
Y : revised data

TABLE D.10 PROBABLE FLOOD WATER LEVEL

(Unit : PWD in m)

WATER LEVEL STATION	RETURN PERIOD (YEAR)												1988	1987	1974
	2	3	5	10	20	30	50	100	200	300	400	500	Flood	Flood	Flood
1) Pubail (BWDB Sta. 7)	6.15	6.34	6.55	6.83	7.09	7.24	7.43	7.67	7.93	8.08	8.17	8.26	7.29	6.90	6.95
2) Demra (BWDB Sta. 7.5)	5.89	6.07	6.27	6.53	6.77	6.91	7.09	7.32	7.56	7.70	7.79	7.87	7.10	6.46	6.58
3) Nayarhat (BWDB Sta. 14.5)	7.49	7.80	8.14	8.56	8.98	9.21	9.51	9.91	10.31	10.54	10.71	10.84	9.90	8.74	8.44
4) Mill Barak (BWDB Sta. 42)	5.78 (5.82)	6.03 (6.04)	6.30 (6.29)	6.65 (6.59)	6.98 (6.89)	7.17 (7.09)	7.40 (7.27)	7.72 (7.56)	8.04	8.23	8.36	8.46	7.54	6.60	6.57
5) Hariharpara (BWDB Sta. 43)	5.45	5.66	5.89	6.19	6.47	6.63	6.82	7.10	7.37	7.53	7.64	7.72	7.17	6.23	6.34
6) Savar (BWDB Sta. 69)	7.17	7.45	7.76	8.14	8.52	8.73	9.00	9.36	9.72	9.93	10.08	10.20	9.68	8.30	7.80
7) Kalatia (BWDB Sta. 70)	6.58	6.83	7.09	7.42	7.75	7.94	8.17	8.48	8.79	8.98	9.11	9.21	8.91	7.53	7.12
8) Kalagachia (BWDB Sta. 71)	5.33	5.46	5.61	5.81	5.99	6.09	6.23	6.40	6.58	6.69	6.75	6.81	5.97	5.92	-
9) Rakabi Bazar (BWDB Sta. 71A)	5.46	5.61	5.78	6.00	6.20	6.31	6.46	6.65	6.85	6.97	7.05	7.11	6.43	6.02	6.07
10) Demra (BWDB Sta. 179)	5.82	5.99	6.18	6.42	6.65	6.78	6.95	7.17	7.40	7.53	7.61	7.69	-	6.38	6.60
11) Narayanganj (BWDB Sta.180)	5.56	5.71	5.88	6.10	6.30	6.42	6.57	6.77	6.97	7.09	7.17	7.23	6.63	6.09	6.23
12) Tongi (BWDB Sta. 299)	6.28 (6.46)	6.54 (6.70)	6.82 (6.97)	7.18 (7.33)	7.53 (7.67)	7.72 (7.86)	7.96 (8.11)	8.30 (8.43)	8.63	8.83	8.96	9.07	7.96	7.02	7.10
13) Mirpur (BWDB Sta. 302)	6.30 (6.42)	6.59 (6.64)	6.90 (6.91)	7.30 (7.25)	7.68 (7.58)	7.90 (7.76)	8.17 (8.00)	8.53 (8.31)	8.90	9.12	9.27	9.39	8.39	7.30	7.09

Notes : 1) The results of the check survey for the water level gauging stations of Mill Barak, Mirpur, Tongi and Demra(Sta. 7.5) conducted by 1987 JICA STUDY are reflected.

2) Water levels in the parentheses are probable water levels of 1987 JICA STUDY.

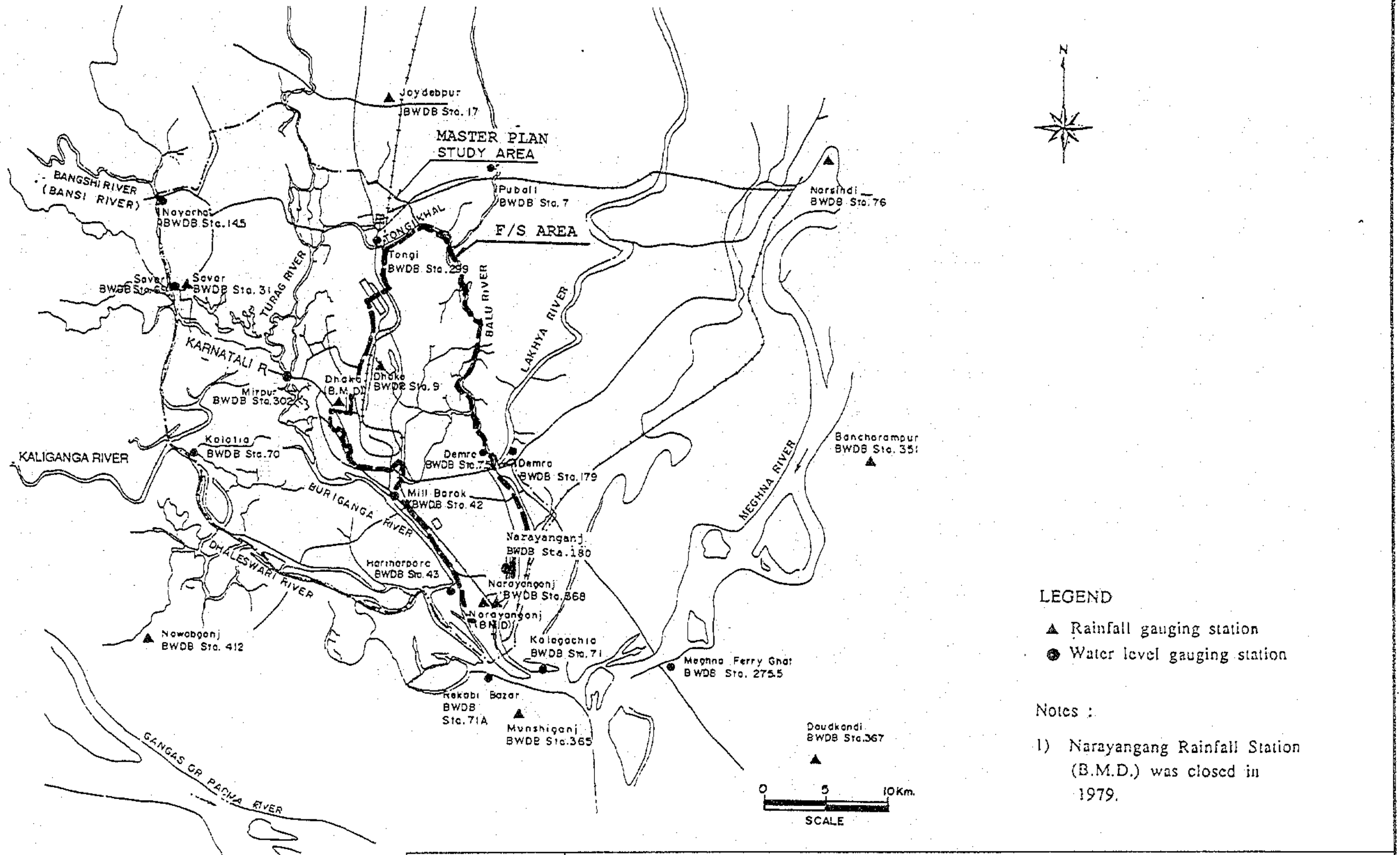


FIG. D.1 RIVER SYSTEM AND GAUGING STATIONS IN AND AROUND THE STUDY AREA

GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH

JICA

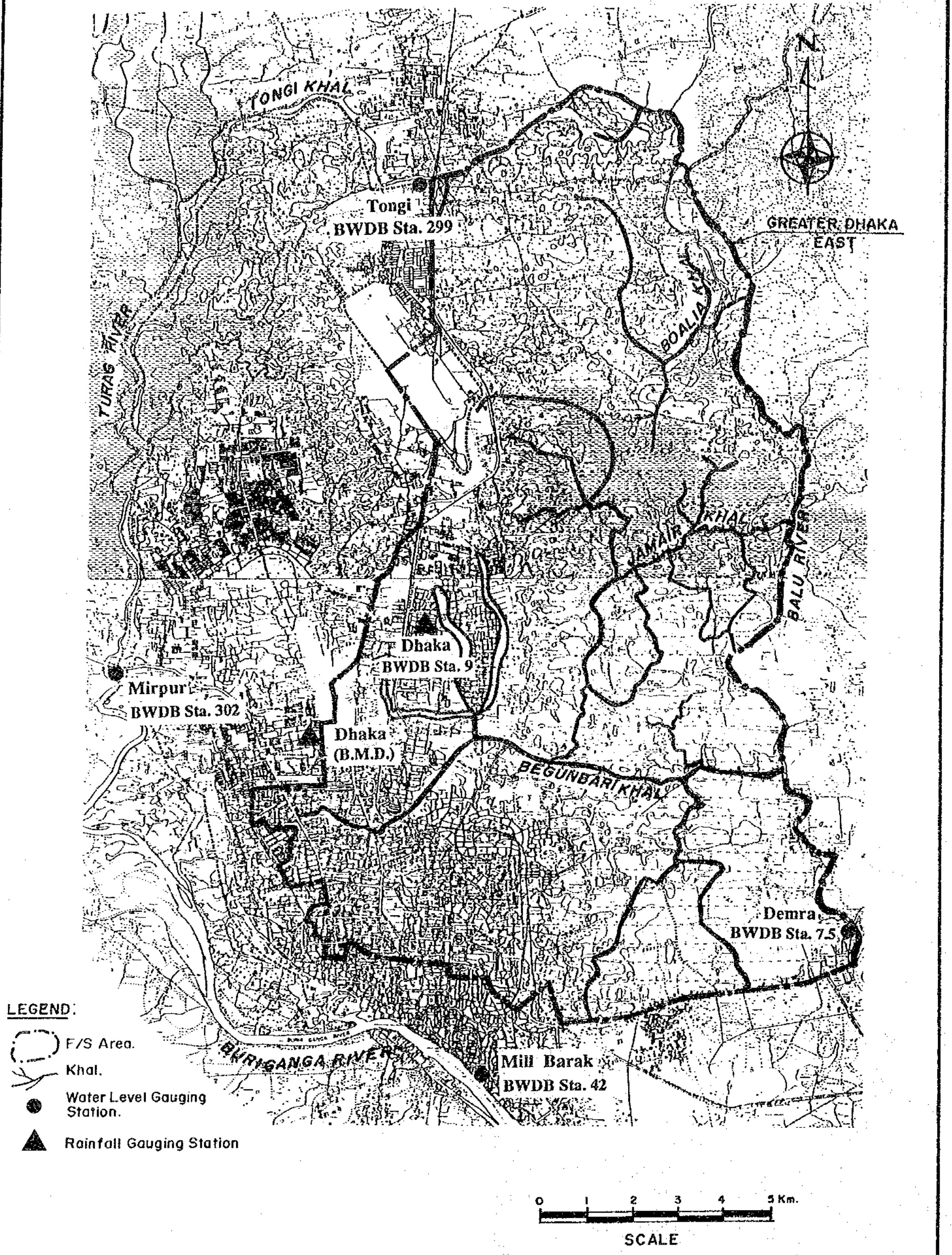


FIG. D.2(1) KHAL SYSTEM OF GREATER DHAKA EAST

GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH

JICA

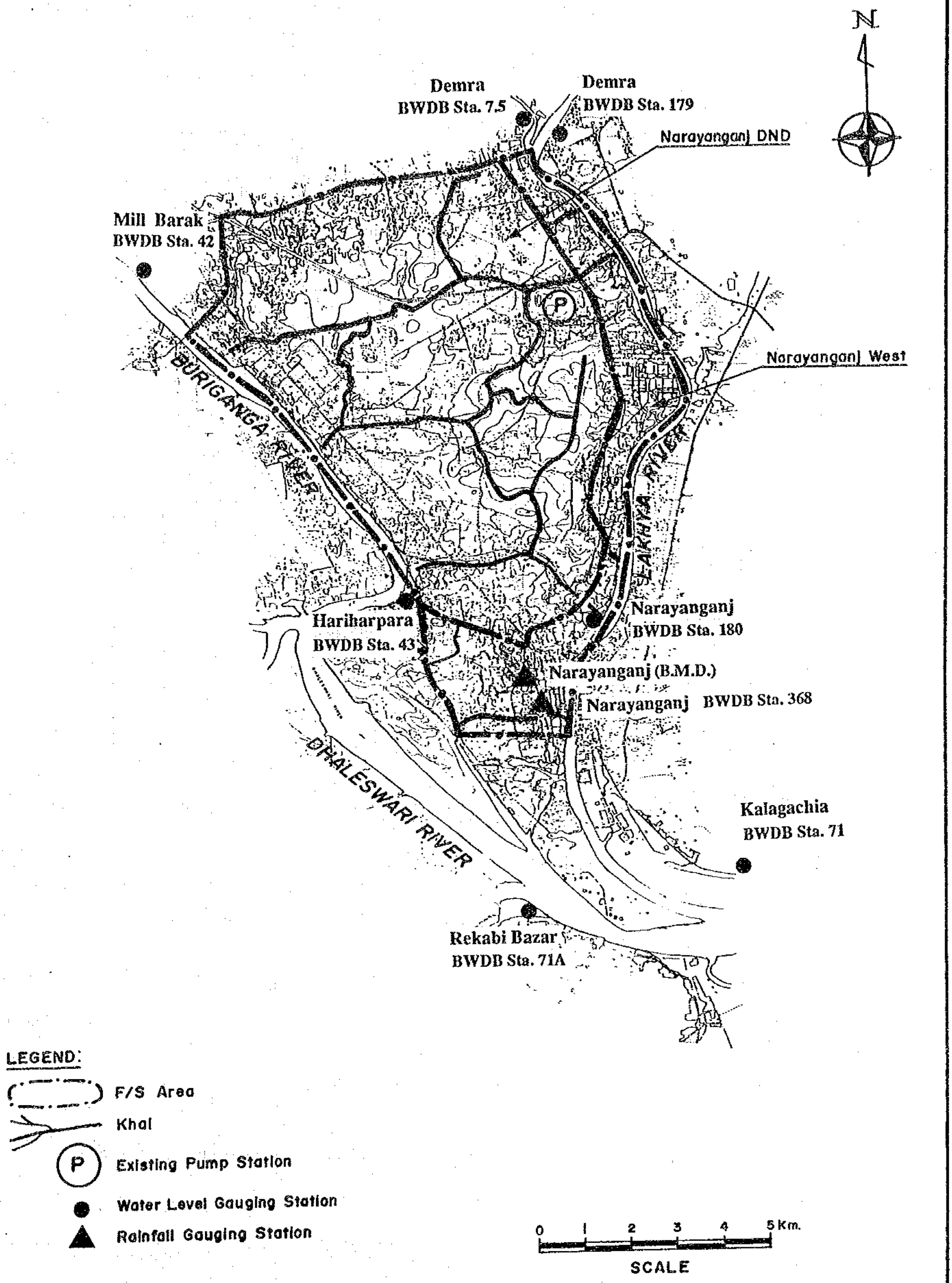
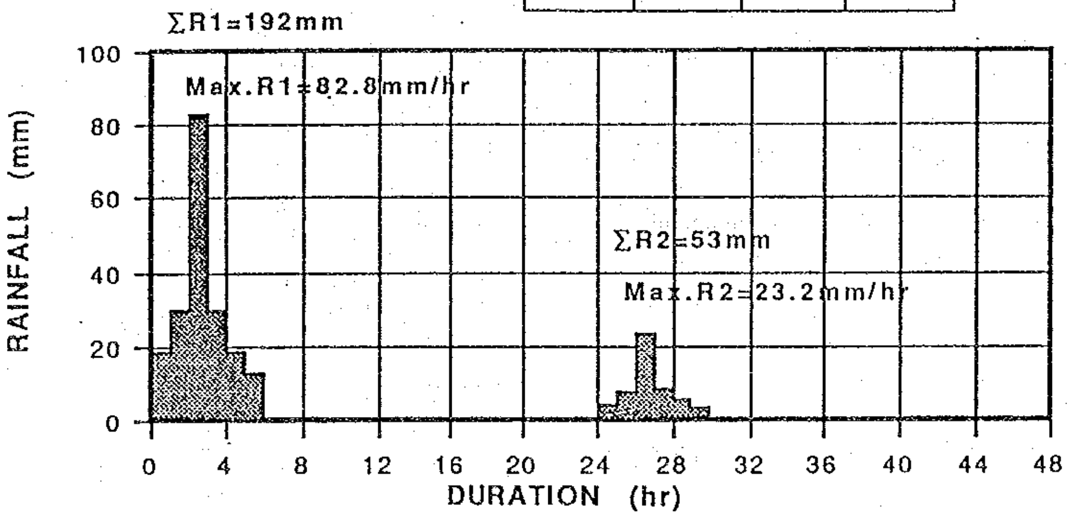


FIG. D.2(2) KHAL SYSTEM OF DND AND NARAYANGANJ WEST

GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH

HOURLY DISTRIBUTION

hr	%	R1	R2
1	9	17.4	4.8
2	15	28.3	8.0
3	44	82.8	23.2
4	16	30.6	8.5
5	9	18.0	5.0
6	7	14.9	3.5
TOTAL	100	192.0	53.0

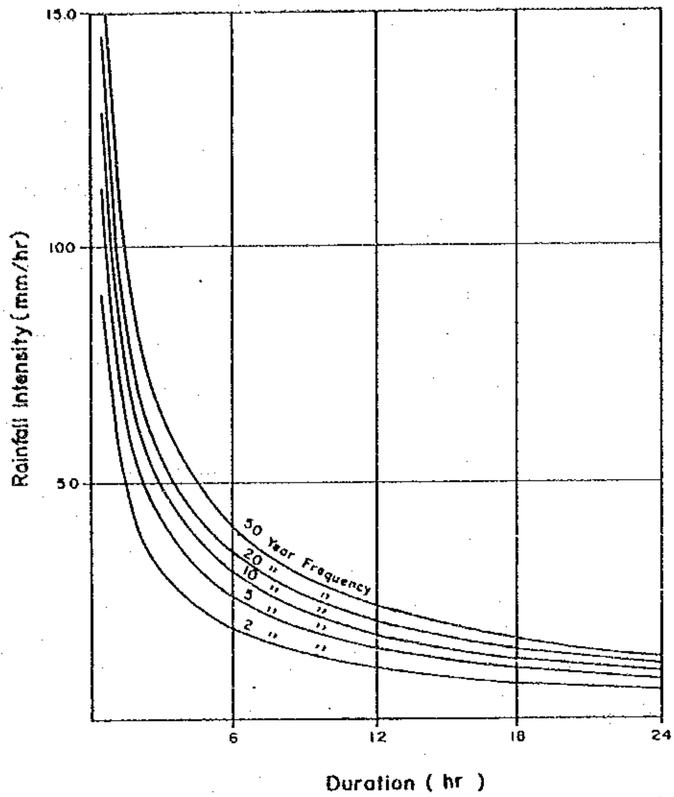


Source :

JICA; Study on Storm Water Drainage System Improvement Project in Dhaka City, 1987

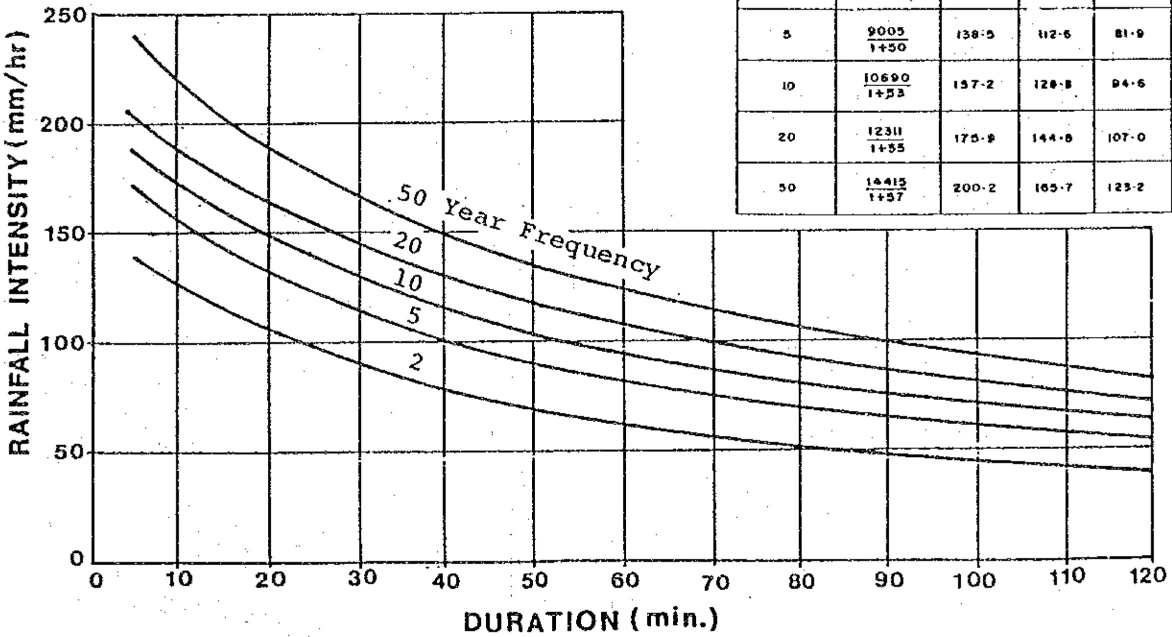
FIG. D.3 PROPOSED DESIGN HYETOGRAPH FOR PUMP DRAINAGE PLAN

GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH



RAINFALL INTENSITY-DURATION FORMULA

RETURN PERIOD	EQUATION	RAINFALL INTENSITY			
		15	30	60	120
2	$\frac{6689}{1+44}$	113·4	90·4	64·3	40·8
3	$\frac{7674}{1+47}$	123·8	99·7	71·7	46·0
5	$\frac{9005}{1+50}$	138·5	112·6	81·9	53·0
10	$\frac{10690}{1+53}$	157·2	128·8	94·6	61·8
20	$\frac{12311}{1+55}$	175·9	144·8	107·0	70·3
50	$\frac{14415}{1+57}$	200·2	165·7	123·2	81·4



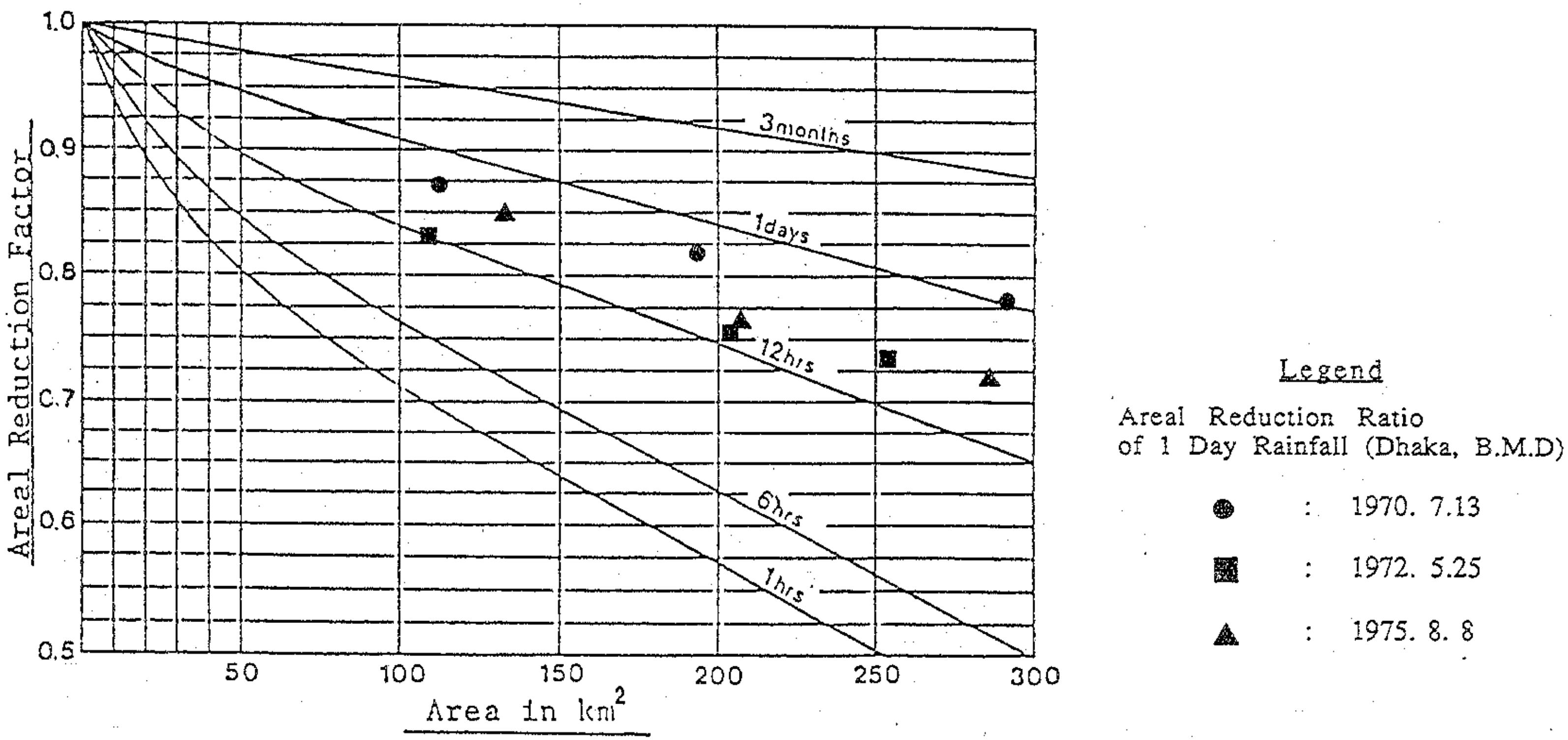
Source :

JICA; Study on Storm Water Drainage System Improvement Project in Dhaka City, 1987

FIG. D.4 RAINFALL INTENSITY AND DURATION RELATIONSHIP

GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH

JICA



Source :

NEDECO ; master Plan for Drainage and Flood Control of Jakarta, 1973

FIG. D.5	AREAL REDUCTION CURVES FOR POINT RAINFALL
GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH	

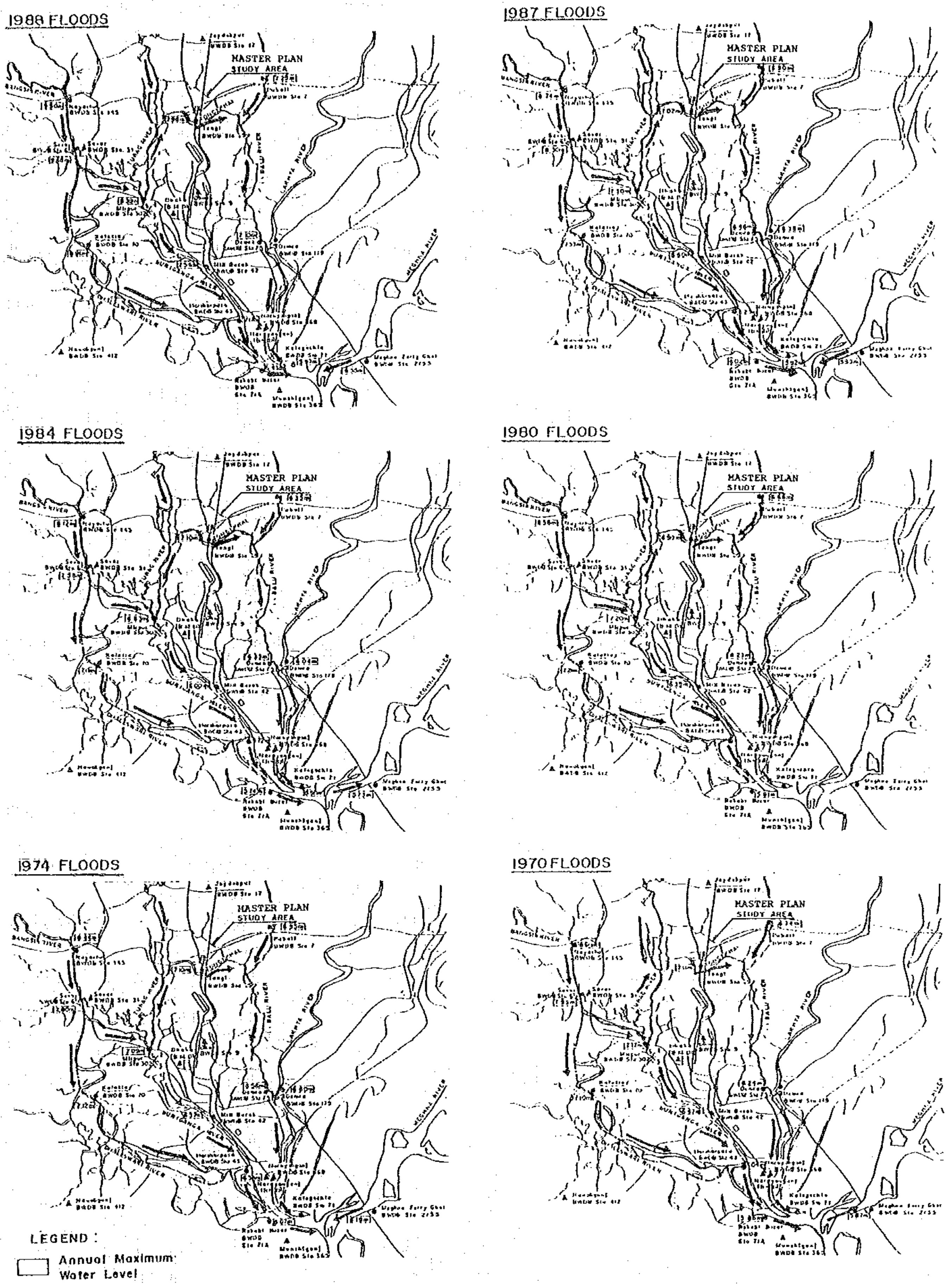


FIG. D.6 ESTIMATED FLOW DIRECTION OF MAJOR FLOODS

GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH

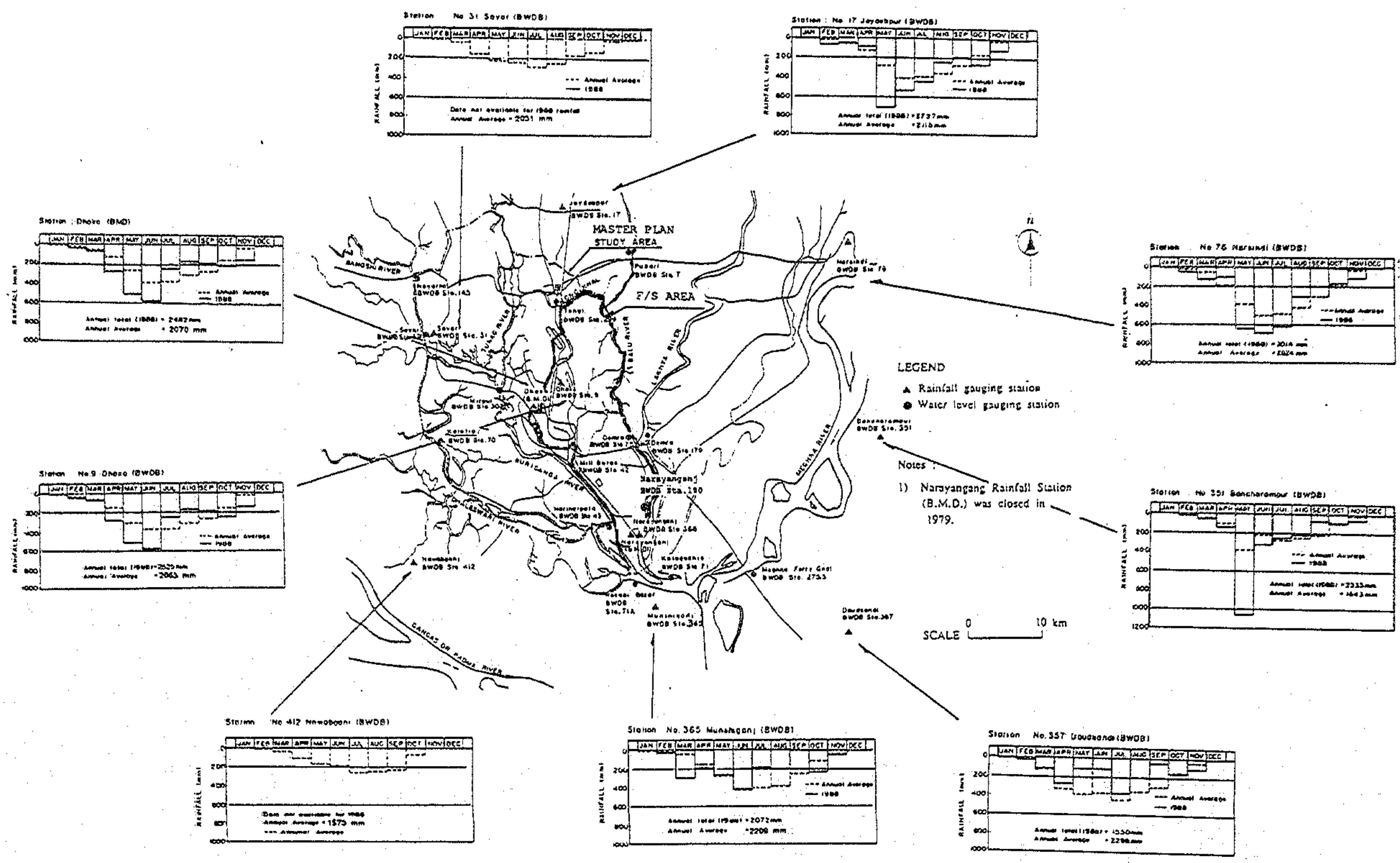


FIG. D.7 MONTHLY RAINFALL-1988 AND ANNUAL AVERAGE

GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH

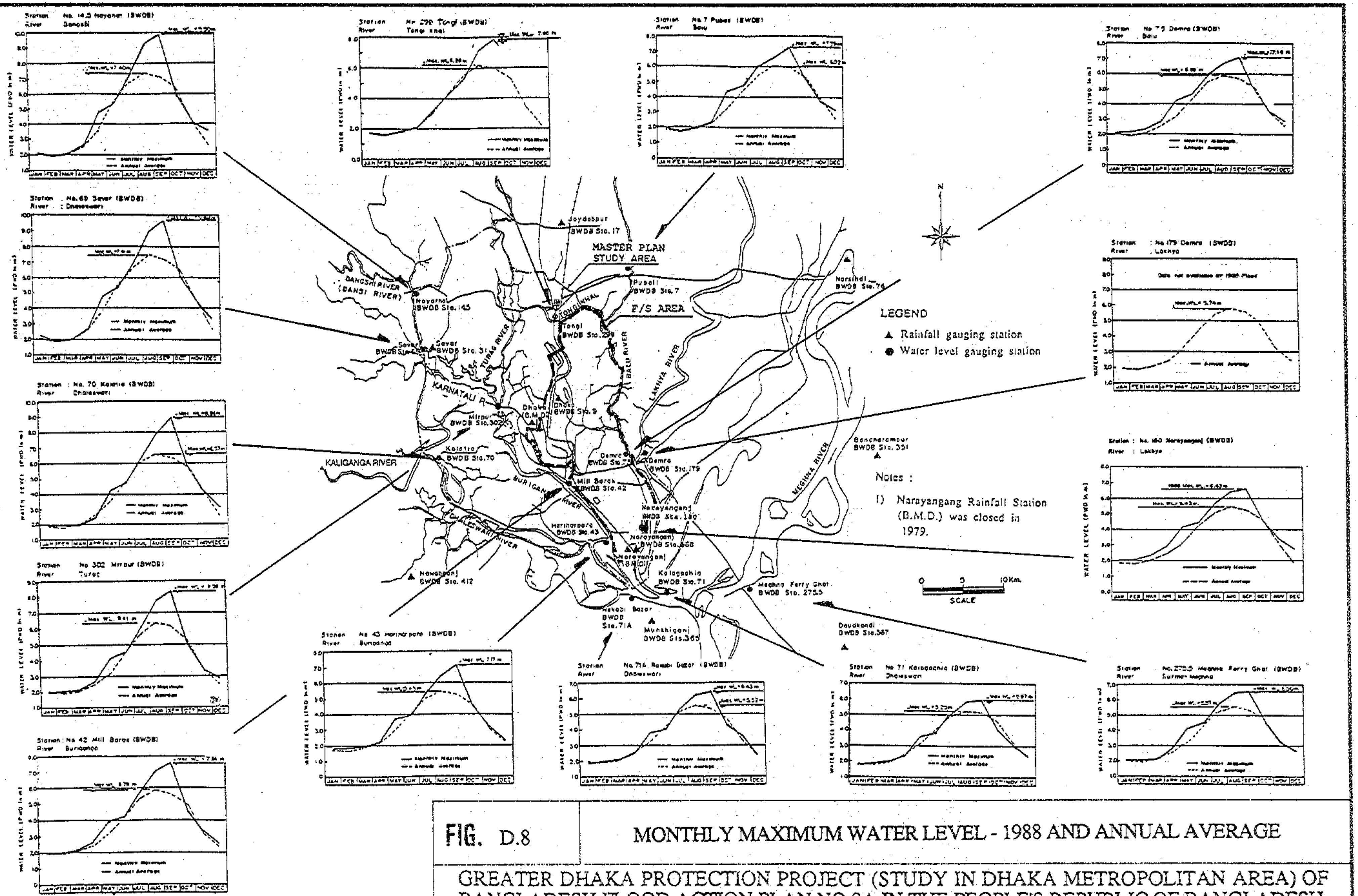


FIG. D.8 MONTHLY MAXIMUM WATER LEVEL - 1988 AND ANNUAL AVERAGE

GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH

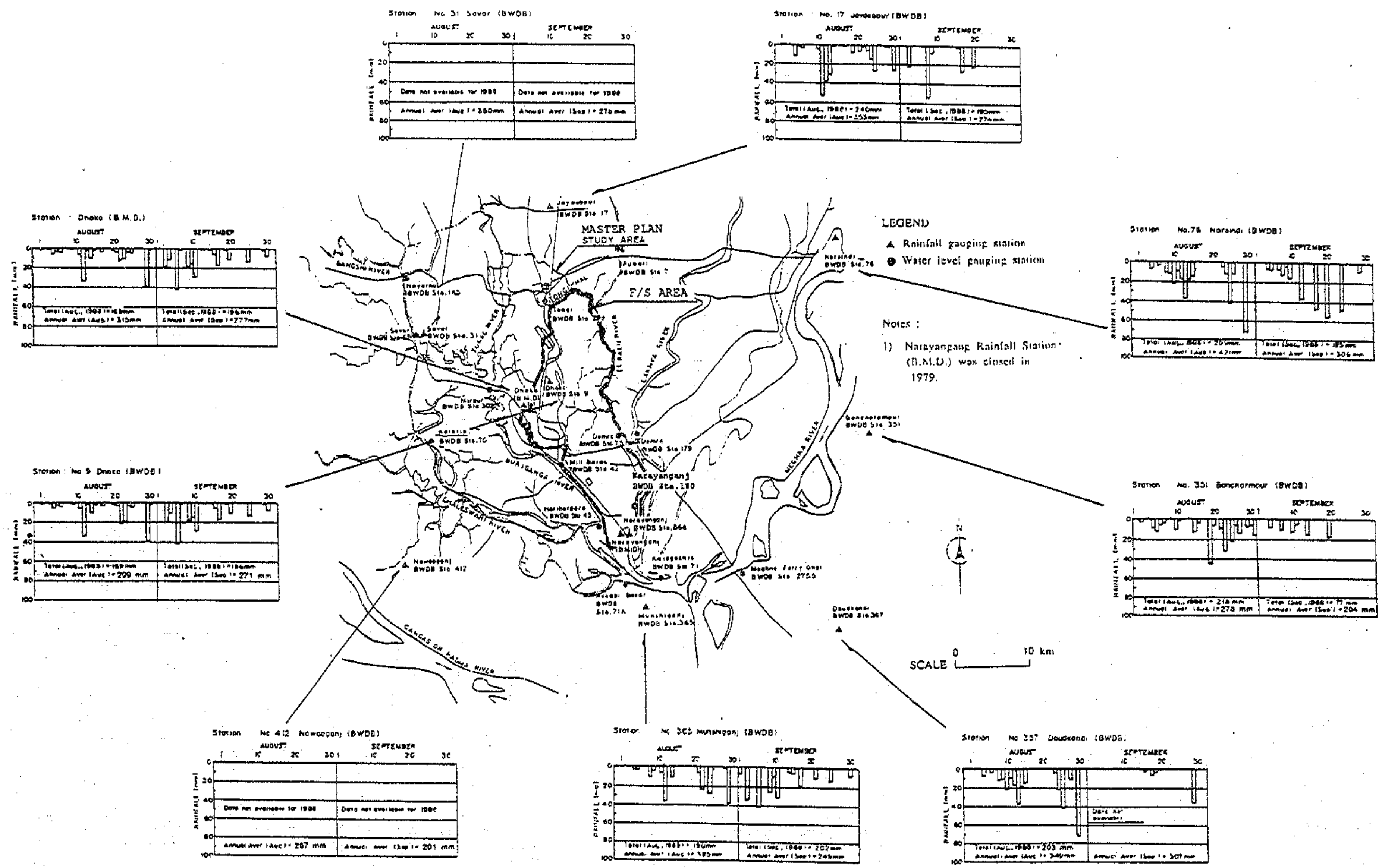


FIG. D.9 DAILY RAINFALL DURING 1988 FLOODS

GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH

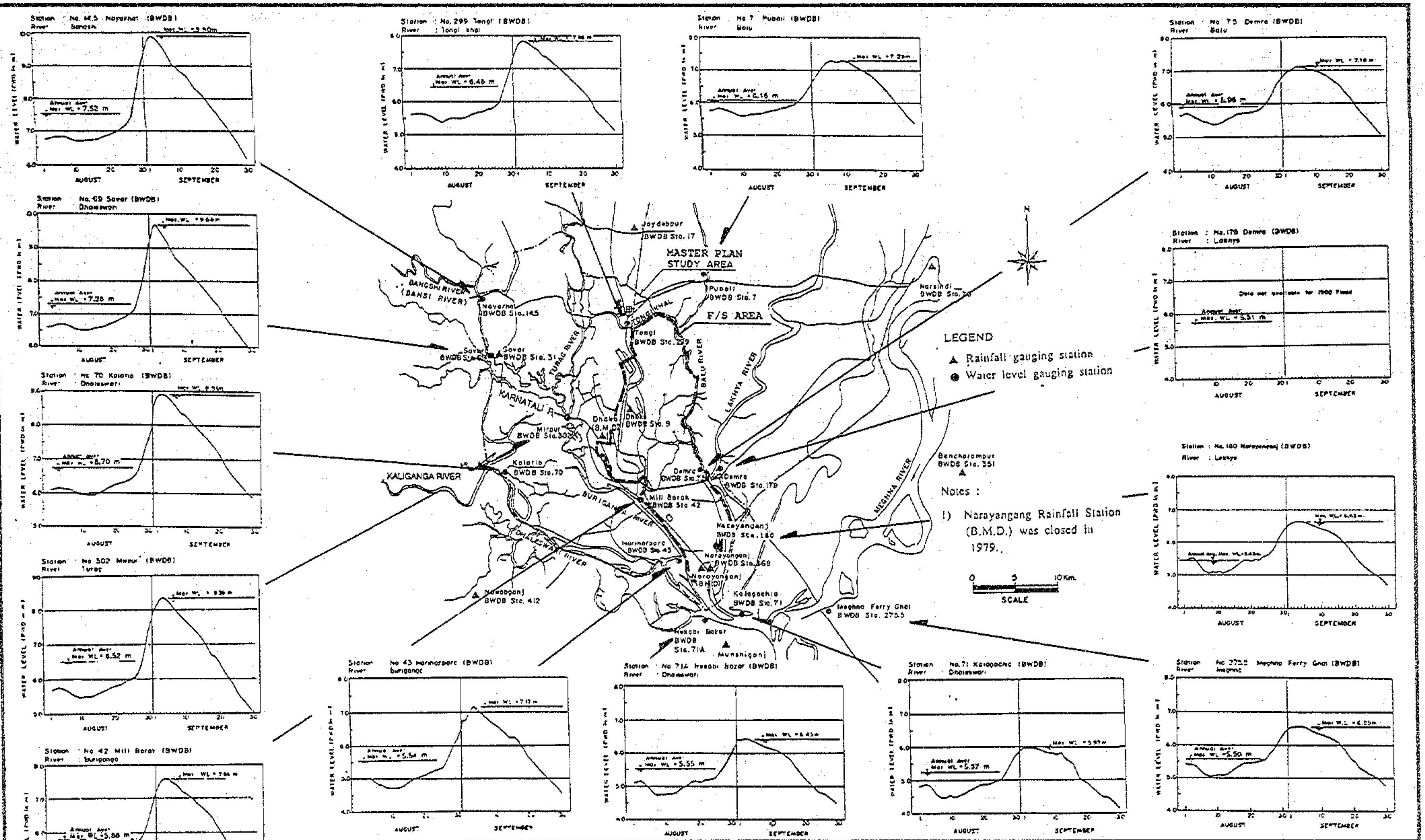
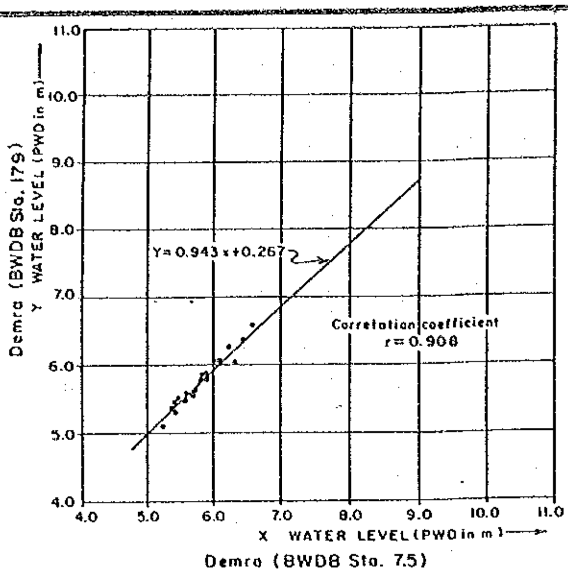
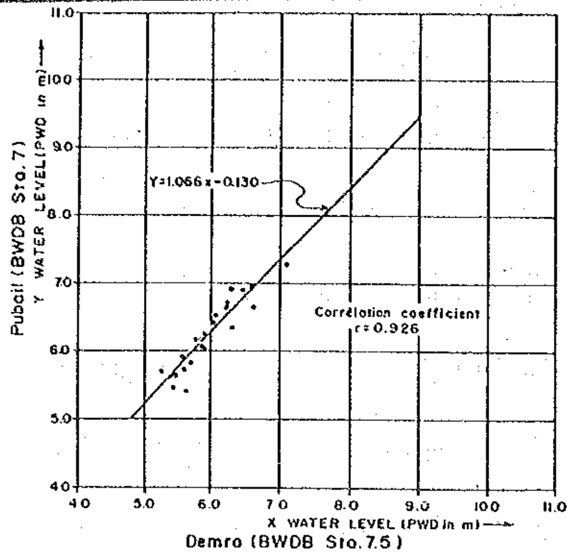


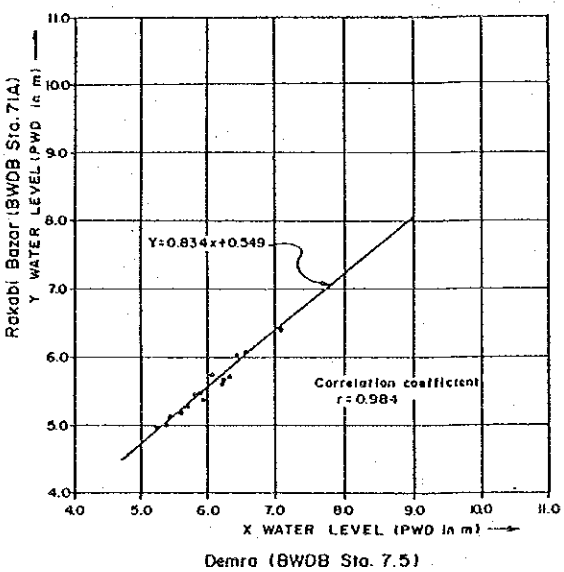
FIG. D.10 DAILY MAXIMUM WATER LEVEL DURING 1988 FLOODS

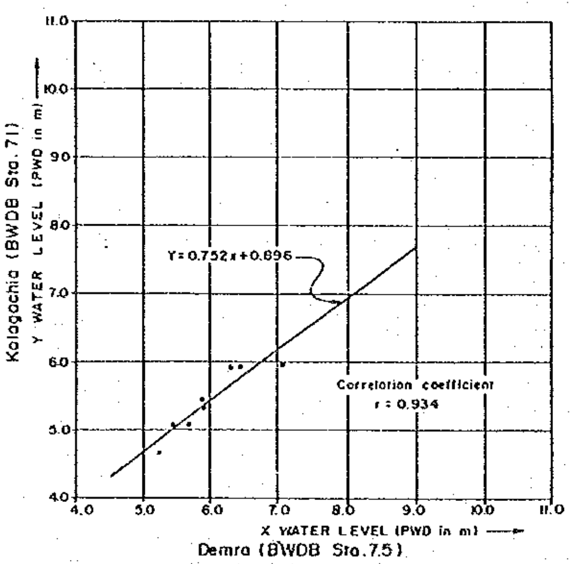
GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH



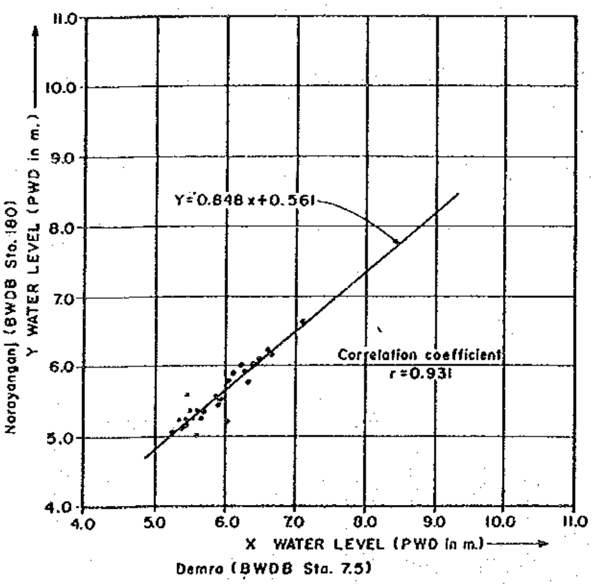


Notes: 1) Water level data of Demra (Sta. 7.5) are supplemented by that of Demra (Sta. 179) using their correlation.





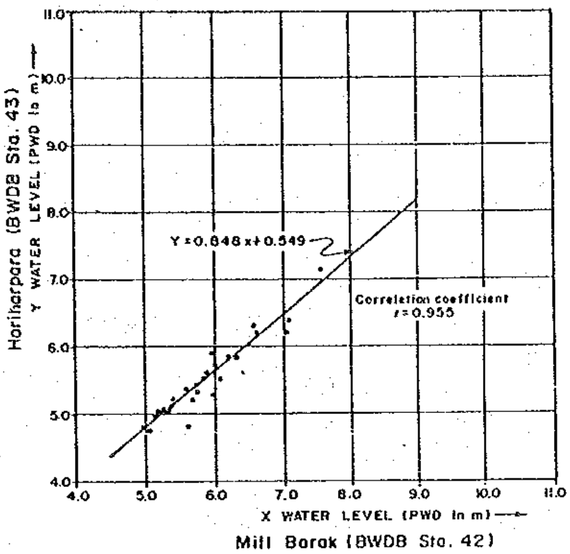
Notes: 1) Water level data of Demra (Sta. 7.5) are supplemented by that of Demra (Sta. 179) using their correlation.

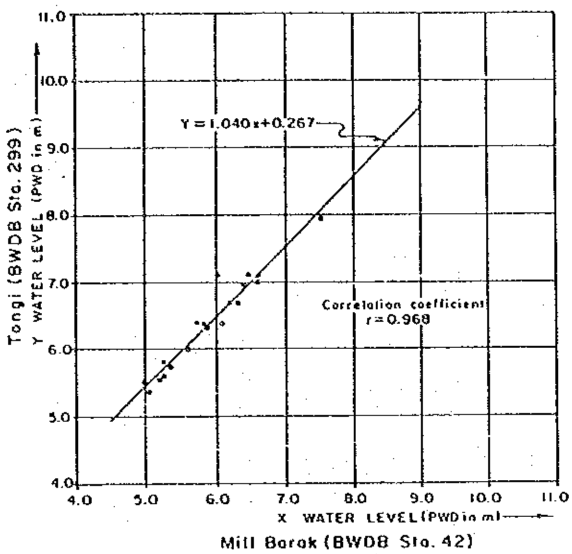


Notes:- 1) Water level data of Demra (Sta. 7.5) are supplemented by that of Demra (Sta. 179) using their correlation.

FIG. D.11(1) CORRELATION AMONG WATER LEVEL GAUGING STATIONS (1/3)

GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH





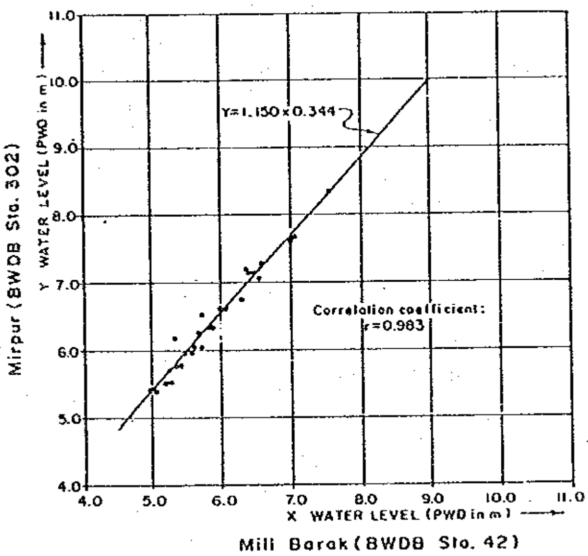
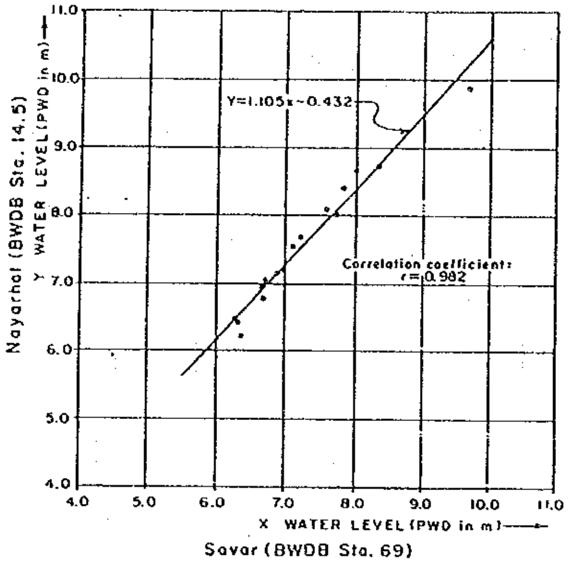


FIG. D.11(2) CORRELATION AMONG WATER LEVEL GAUGING STATIONS (2/3)



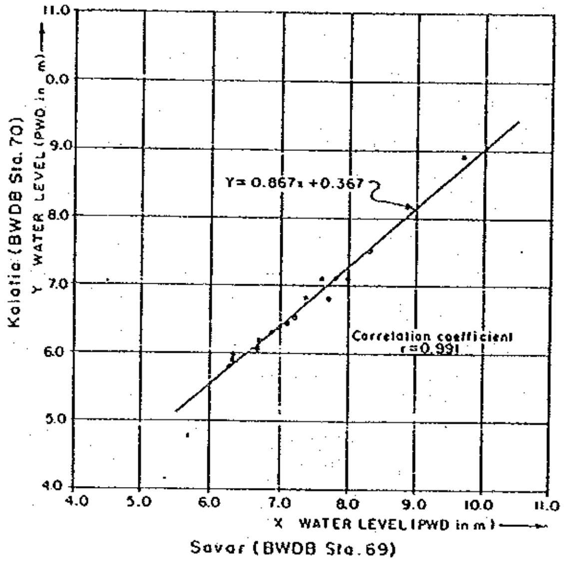


FIG. D.11(3) CORRELATION AMONG WATER LEVEL GAUGING STATIONS (3/3)

GREATER DHAKA PROTECTION PROJECT (STUDY IN DHAKA METROPOLITAN AREA) OF BANGLADESH FLOOD ACTION PLAN NO.8A IN THE PEOPLE'S REPUBLIC OF BANGLADESH

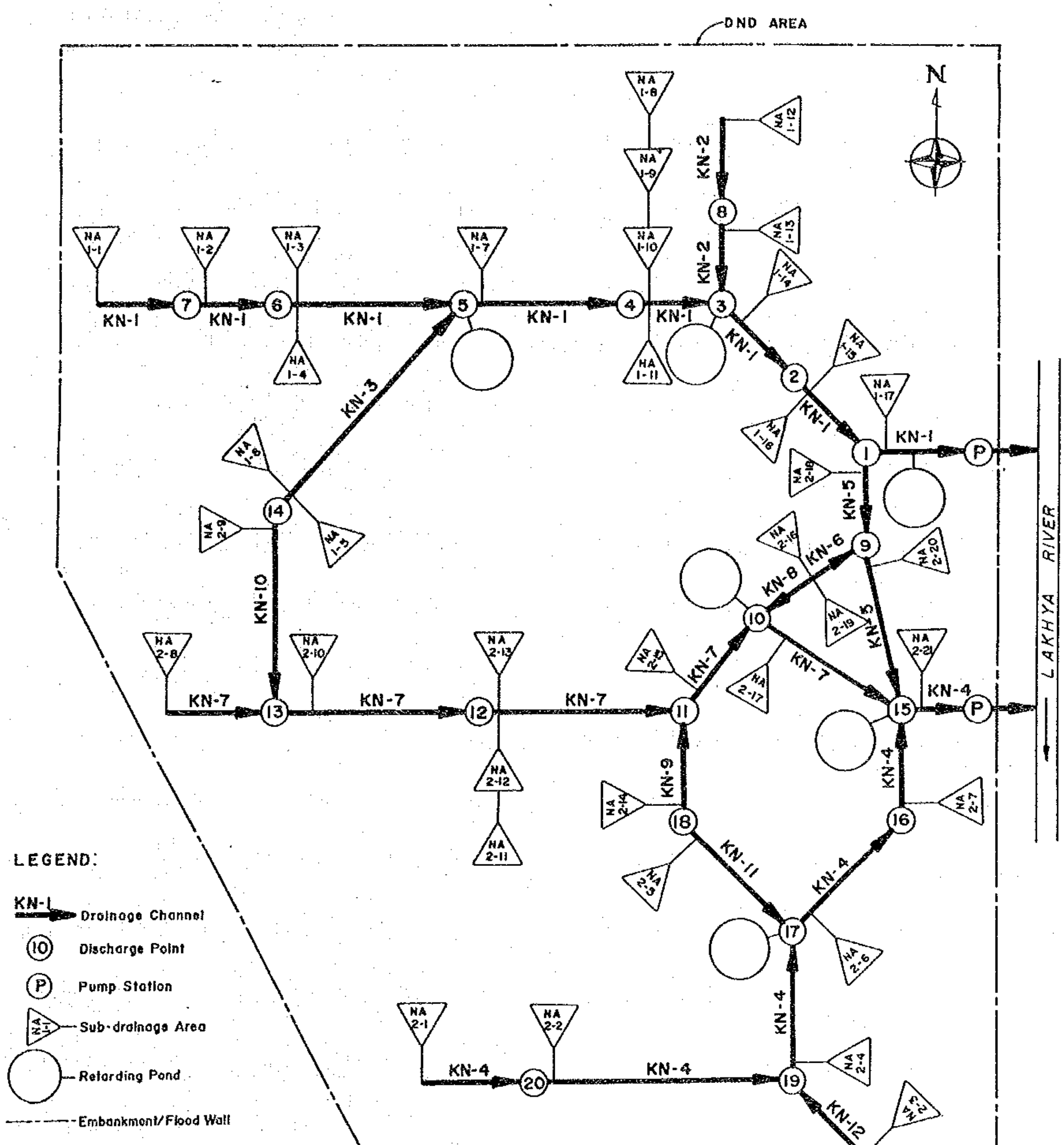


FIG. D.12 PROPOSED SIMULATION MODEL OF NARAYANGANJ DND

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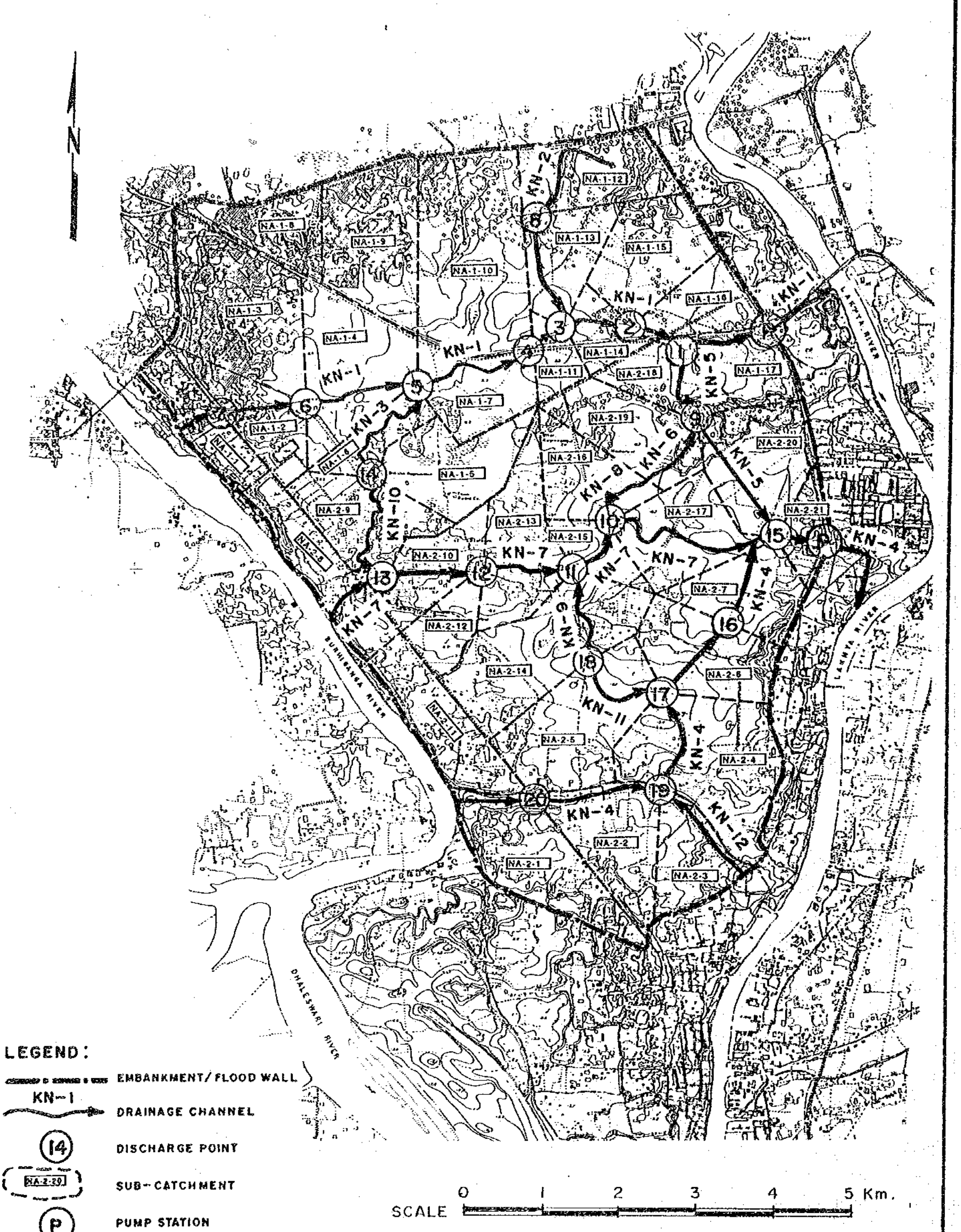

FIG. D.13	DRAINAGE CHANNELS AND SUB-CATCHMENTS OF NARAYANGANJ DND

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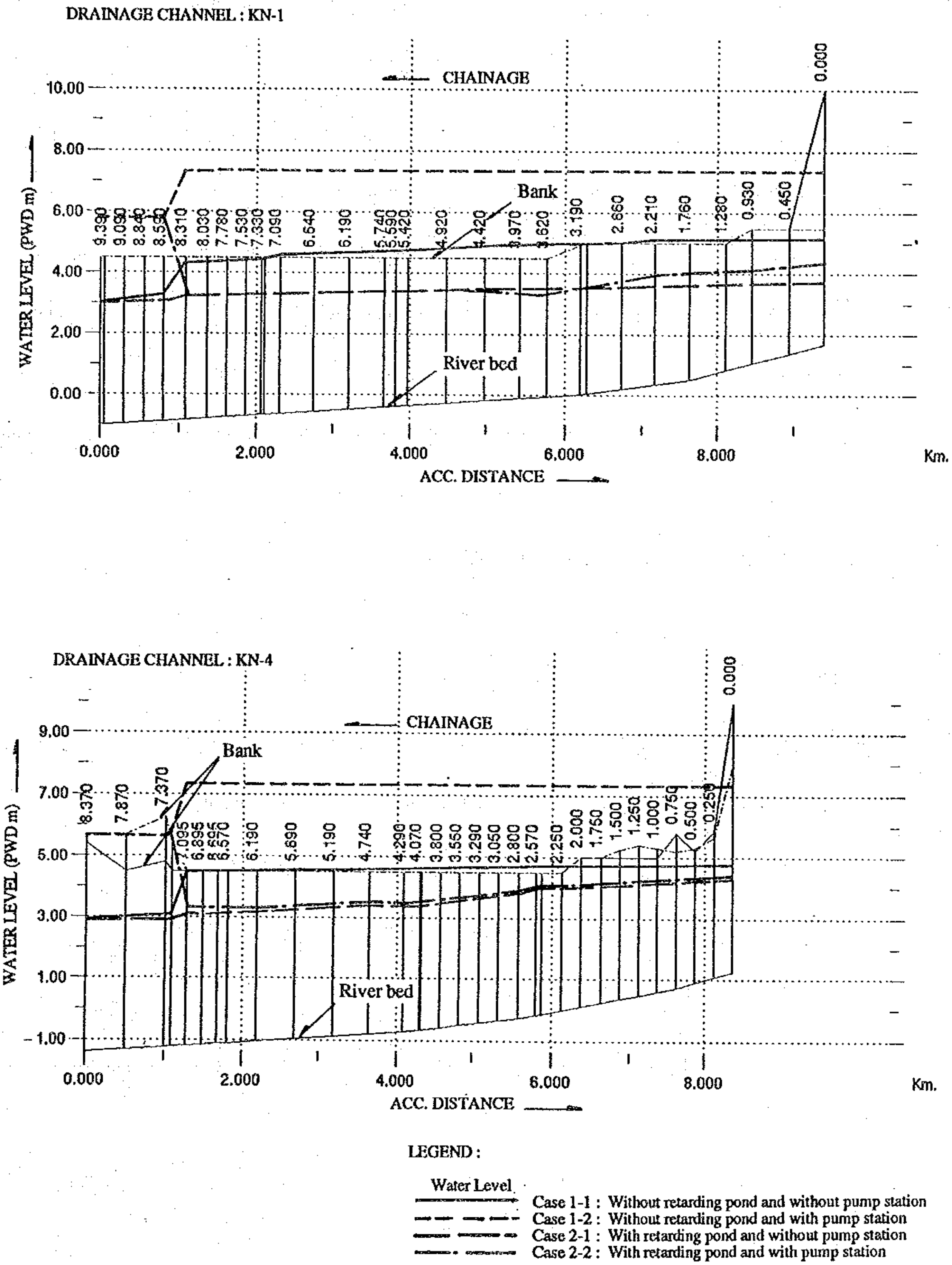

FIG. D.14	PROFILE OF SIMULATED PEAK WATER LEVEL OF NARAYANGANJ DND

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